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Laying a Foundation for Computing in Outdoor Recreation

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ABSTRACT

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Mobile computing allows individuals to bring computing with them into the outdoors. This creates a new situation in which individuals can stay connected even when trying to "get away from it all." Questions arise from this juxtaposition regarding whether the inclusion of computing in these activities is a positive or a negative. Evidence exists supporting both conclusions. We posit that computing can contribute positively to outdoor recreation without distracting. This dissertation details work undertaken in two phases which explores how computing can accomplish this goal.

Phase 1 explored how individuals are already using computing technology in hiking, and culminated with the development of a model describing individuals' decisions regarding technology use on the trail. In Phase 2, we developed a vision which navigates the tension between the connection technology provides to our day-to-day lives and the desire to disconnect, along with prototypes which serve as an embodiment of this vision.

We found that computing is in wide use by hikers, and through qualitative data analysis we developed a *Two Worlds* model which describes their decisions regarding technology use when hiking. This model provides a space which can be probed and explored in future work. Our vision guides careful growth in the inclusion of computing in outdoor recreation, allowing computing to support activities without becoming a distraction.

Our work makes important empirical, theoretical, and artifact contributions to the field of HCI. It also identifies interesting areas of exploration, some of which have already informed the development of our *Two Worlds* model, and some of which remain largely unexplored. In this sense, our work has both blazed new trails in exploring computing's place in outdoor recreation and identified "side trails" for further exploration by ourselves and others. We look forward to this work and its results.

Keywords: human-computer interaction, HCI, outdoors, hci outdoors, hiking, mobile computing

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Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

Figure 1.1: A woman using a smart watch in the desert. The HCI community has the opportunity to investigate and explain this kind of interaction. This understanding will help us build interactive systems which enhance and enable outdoor recreation experiences. (Photo credit: Blazej Lyjak, shutterstock.)

Modern mobile technology is such that individuals carry small but remarkably capable computers with them nearly everywhere they go. This leads to computing's inclusion in activities and contexts where it was previously absent, changing these contexts and activities in both subtle and obvious ways. One such context is outdoor recreation, where use of technology can be readily observed in many different forms.

Figures 1.1 and 1.2 illustrate computing technology use during outdoor recreation. Figure 1.1 shows a woman interacting with a smartwatch in the outdoors. There are many reasons why she may choose to interact with her smartwatch at this time. She could be

Figure 1.2: A woman using a cell phone with a bare hand in a cold forest. Another opportunity facing the HCI community is designing and engineering systems which are comfortable for use in outdoor environments. (Photo credit: Mila Drumeva, shutterstock.)

checking her location or finding her bearings on a long hike or trail run. Perhaps, she just received an important notification regarding an emergency back home. Looking at her watch for any one of these reasons could also result in getting sucked into reading interesting tweets from her notifications list. Therefore, her use of the smartwatch could serve as a distraction from or an enabler for her outdoors activity. She likely has her own opinions of its place and purpose.

Figure 1.2 shows a different woman using a cell phone on a cold day in the forest. She removed her glove to use the phone touch screen despite the cold air. Similar to the woman in Figure 1.1, the outside observer can only guess at her motive for smartphone use. It could plausibly help her decide which route to take on her ski run or lead her to succumb to a social media addiction. She could lose feeling in her fingertips making it more difficult to interact with the touch screen interface.

Figure 1.2 also highlights technical and environmental aspects of computing and technology use in the outdoors. A smartphone is designed to be a very general-purpose device, necessitating a visual- and touch-based interface. It is also meant to be used in relatively tame conditions. Neither of these characteristics is conducive to outdoor recreation use. A different interface modality might have been a better fit for outdoors interaction. Tactile, haptic, or gesture input/output might allow for interaction without removal of one's glove in cold weather. Also, the cold and potentially wet environment may not be an ideal operating environment for a computing device.

Although our discussion has focused largely on outdoor recreation, Figures 1.1 and 1.2 illustrate important questions about the inclusion of computing in any new context:

- How does computing affect the experience?
- Are the experiential effects of computing a net positive or negative?
- What systems should be built for outdoor activity and what purposes and roles should they fill?
- How can computing systems provide utility without distraction?

1.1 Benefits from Time Spent in Natural Settings

Traditionally, time spent in outdoor recreation is intended to be restorative, restful, peaceful, reinvigorating, and in general a break from the stress and pressures of daily life. Robert Marshall, a forester and pioneer of wilderness preservation, wrote in 1934:

> In a world over-run with split second schedules, physical uncertainty and man-made superficiality ... life's most splendid moments come in the opportunity to enjoy undefiled nature. [59].

Psychological and sociological research also supports the idea of nature being a restorative [44] or stress-reducing [80] environment. Kaplan and Kaplan [43] posit that time spent outdoors restores one's ability to hold directed attention. Directed attention [35] is one's ability to focus on a task in the presence of distractions. Directed attention is used to study for an exam, prepare a tax return or even maintain a polite conversation. These tasks become difficult or impossible when one's directed attention is depleted.

Drawing from nearly three decades of their own research, Kaplan and Kaplan present a theory of attention restoration in which time spent in environments with four properties can restore directed attention. The four properties are: fascination, being away, compatibility, and extent. The Kaplans argue that many outdoor spaces provide all of these properties, and as such are particularly good examples of such restorative environments.

Similarly, Ulrich et al. [80] studied stress recovery in individuals when exposed to a natural environment. In their study, they measured key stress indicators: heart rate, muscle tension, skin conductance, and pulse transit time. While doing so, they showed subjects a "stress-inducing" video involving staged accidents in a wood shop setting. They then measured stress indicators while showing subjects videos of either natural or man-made environments. They found that natural environments better mollified participant stress, concluding:

> ...an encounter with most unthreatening natural environments will have a stress reducing or restorative influence, whereas many urban environments will hamper recuperation. [80].

1.2 Computing in Outdoor Recreation

In each of the preceding works, nature's restorative benefit seems driven by the opportunity to escape things that cause stress in daily life. However, by design, mobile technology connects users with the world at large constantly reminding of tasks, appointments, news stories, errands, work, and other bits of our daily routine that we seek to escape in the outdoors. While these reminders are generally beneficial in day-to-day life, this is not helpful when seeking restoration in an outdoor setting.

On the other hand, the capabilities and power of smartphones are useful in nearly any situation, particularly when outdoors. Apps exist for hiking[1], tracking one's path and

[1] https://www.alltrails.com/mobile

sharing it with others[2], finding mountain biking trails[3], birdwatching[4], fishing[5], and engaging in countless outdoor pursuits. Modern computing technology has shown itself to be useful in outdoor recreation.

In a seminal envisionment of the future of computing in 1991, Mark Weiser concluded with an aspiration that links interactive computing with outdoor recreation. He wrote:

> There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods. [84]

Nearly 30 years since Weiser's statement, the amount of digital "information available at our fingertips" carried on a walk in the woods is astonishing; while computing power has improved significantly, our contentment during computer use has not. We still find a walk among the trees far more relaxing than using a computer. In this dissertation, we detail work that seeks to explore computing's potential to contribute to restorative outdoor activities while allowing individuals the freedom to focus on the natural "information available at [their] fingertips" rather than on their computing devices.

1.3 Research Questions

Thus we arrive at the central questions explored in this dissertation:

- How are hikers in the United States using interactive computing while hiking?
- How should interactive computing systems be designed to improve the hiking experience?

[2]https://www.strava.com/mobile
[3]https://www.trailforks.com/apps/map/
[4]https://www.sibleyguides.com/about/the-sibley-eguide-to-birds-app/
[5]https://www.cabelas.com/category/Top-Fishing-Apps/1980688680.uts

Rather than attempting to explore all categories of outdoor recreation, we chose to focus on hiking. Hiking is representative of outdoor activity for this work because of hiking's broad appeal, low barrier to entry, ubiquity, and consistent presence (as recreation or transportation) in human culture across centuries. Hiking also involves a vast array of existing gear with the potential for design, implementation, and testing of computing systems. We anticipate that some of our findings may generalize to other activities while others will not.

1.4 Overview of Research Methods

We undertook work in two phases, comprising three parts, each with its own individual contribution to Human Computer Interaction (HCI) in general and to HCI Outdoors, specifically. For the remainder of this dissertation, we will refer to the growing research area around computing's inclusion in outdoor activities by the term *HCI Outdoors*.

1.4.1 Phase One

The first phase of our work focused on the present. The goal of this phase was to gain an understanding of current attitudes and preferences toward hiking and technology use when hiking. This understanding informed our further exploration in the second phase of this dissertation and can inform future work by ourselves and others.

Our work in this phase followed an *explanatory sequential* study design [61]. In this design, initial quantitative inquiry serves as a broad base in understanding a given phenomenon. From quantitative results, further questions and areas for deeper inquiry are identified and subsequently explored through qualitative inquiry. Thus qualitative work helps explain areas of interest identified through initial quantitative work.

In the first part of this phase, we conducted quantitative work as outlined above. Results of this part included:

- Construction of clusters of individuals based on hiking and technology preferences

- Identification of correlations between hiking and technology preference clusters
- Understanding the types and numbers of technology items carried when hiking
- Demographic differences in preference

Perhaps most interestingly, we found that in spite of potential concerns regarding distraction and other downfalls, 95% of individuals who responded to our survey (n. 962) prefer to carry a cell phone when hiking. This work is detailed in Chapter 3 of this dissertation.

In the second part if Phase 1, we followed quantitative work with qualitative as per the *explanatory sequential* study design. Our qualitative work sought to understand why individuals carry a cell phone and other electronic devices when hiking, what they use them for, and what individual ideas, relationships, and thought patterns underly the correlations found between hiking and technology preferences. Analysis of short-answer survey responses led to the development of a *Two Worlds* model describing individuals' approaches to technology use when hiking. In this model, individuals adopt and adapt technology to bridge, maintain, or ignore the boundary between the natural world where they go to hike and the civilized world where they live day-to-day.

Further qualitative inquiry via interviews and observation validated and expanded our model and allowed for further exploration of its themes. A new axial theme emerging from interviews was *Curation*, wherein individuals made decisions regarding technology use on the trail with the intent to satisfy their goals and motivations for hiking. The incorporation of this axial theme into the *Two Worlds* model led to a broader understanding of the model and the inclusion of other axial themes previously identified but thought to be outside the scope of the model. Our qualitative work is laid out in Chapters 4 and 5.

1.4.2 Phase Two

While the first phase of this work was grounded in the present, the second phase reaches toward the future. In the second phase, we sought to envision and define directions for ongoing work in HCI Outdoors. We then took steps toward fulfilling that vision within the realm of hiking.

The second phase comprised the development and an initial realization of a vision for computing in outdoor recreation. This vision synthesizes ideas drawn from our own outdoor experience, philosophical and cultural values regarding time spent in nature, research from social sciences, important ideas from within HCI, and results from the first phase of our work. This vision provides guidance for navigating the aforementioned tension between technology's tendency to keep users connected to day-to-day lives and the motivation to "get away from it all" common in outdoor recreation.

Following the tradition of other envisionments in HCI, we developed and built several prototypes which are intended to realize our vision and illustrate various aspects of it. In concert, these prototypes also represent a prototoype of a new type of system which is intended to realize our vision in the realm of hiking: the Hiker Area Network, or HAN.

This vision comprises Chapter 6 and will appear as an invited chapter in a forthcoming book on HCI Outdoors [11].

1.5 Conclusion

Mobile technology allows the inclusion of computing in outdoor activities in ways that were not possible before. This presents both opportunities and challenges. The fledgling research area of HCI Outdoors within the broader HCI community seeks to explore both.

Through research conducted in three parts over two phases, we have explored the juncture between these opportunities and challenges as they stand now and as they may become in the future. Our contributions include:

- Empirical results which broadly outline groups of hikers and their preferences regarding hiking and technology use when hiking as well as questions for further inquiry
- Questions and areas of further inquiry arising from empirical work

- A model, titled the *Two Worlds* model, which was developed and refined through multiple qualitative data-gathering steps, and describes hikers' technology decisions with regards to hiking
- A vision for the future of technology in outdoor recreation which navigates the tension between getting away and staying connected

These parts each contribute to HCI Outdoors specifically and HCI in general. When considered holistically, they create a foundation for understanding HCI in the context of outdoor recreation. We anticipate meaningful research will continue to build on this foundation for years to come.

1.6 Research Contributions in HCI and Evaluating this Dissertation

Wobbrock and Kientz detail seven types of research contributions for HCI [86]: *Empirical, Artifact, Methodological, Theoretical, Dataset, Survey*, and *Opinion*. In the article, the authors discuss characteristics, outline subtypes, and give evaluation criteria for each contribution type.

We characterize our contributions as Empirical, Theoretical, and Artifact contributions. We present quotes from Wobbrock and Kientz [86] in order to clearly describe each contribution type and criteria for evaluating such contributions. We also position our work relative to these contribution types:

- **Empirical**—this contribution type characterizes the quantitative work in the first part of Phase 1—"Empirical research contributions are the backbone of science. They provide new knowledge through findings based on observation and data gathering." [86]
  - *Evaluation:* "Empirical research contributions are evaluated mainly on the importance of their findings and on the soundness of their methods." [86]
- **Theoretical**—Our *Two Worlds* model as derived from results of our quantitative work in the second part of Phase 1 is a *Theoretical* contribution—"Theoretical research

contributions consist of new or improved concepts, definitions, models, principles, or frameworks. They are vehicles for thought." [86]

  - *Evaluation:* "Fully developed theories offer explanatory accounts, not simply observing *that* but explaining *why*...Theoretical research contributions are evaluated based on their novelty, soundness, and power to describe, predict, and explain." [86]

- **Artifact**—Our vision developed in Phase 2 is an *Envisionment* artifact, while HANs represent an early-stage *System* or *System Type* artifact—"HCI is driven by the creation and realization of interactive artifacts. Whereas empirical contributions arise from descriptive discovery driven activities (science), artifact contributions arise from generative design-driven activities (invention). Artifacts, often prototypes, include new systems, architectures, tools, toolkits, techniques, sketches, mockups, and envisionments that reveal new possibilities, enable new explorations, facilitate new insights, or compel us to consider new possible futures. New knowledge is embedded in and manifested by artifacts and the supporting materials that describe them." [86]

  - *Evaluation:* "New systems, architectures, tools, and toolkits are evaluated in a holistic fashion according to what they make possible and how they do so...New design expressions, including sketches, mockups, and envisionments, are evaluated by how insightful, compelling, and innovative is their portrayal. Of particular importance is how well designs negotiate trade-offs and hold competing priorities in balance." [86]

1.7 Introducing Terms from Qualitative Research

In the spirit of clarity, we present a brief introduction of various terms which will be used throughout this dissertation in referring to our results. We define these terms here in order to more carefully differentiate between the various parts of our results and to make clear how they fit together.

The largest body of terms we define here are related to qualitative data analysis. We note that although we choose to use these particular terms, other terms are also in wide use among qualitative researchers to refer to the same types of constructs [61]. These terms are used to describe theoretical constructs which are inductively derived from data via the constant comparative method, which is discussed in further detail in a later chapter.

- *Code*–a *code* is a low-level unit of knowledge which is derived directly from qualitative data. Codes describe an idea which is encountered within data, and are derived through careful analysis. A code has a name which is either descriptive of the underlying data or derived directly from participants' own phraseology.
- *Theme*–a *theme* is a broader idea which has been derived through comparison of codes. A theme encompasses and gives broader meaning to a set of codes. Themes are derived through comparing, contrasting, and grouping codes.
- *Axial Theme*–an *axial theme* is a central uniting concept among one or more themes. Often called a core theme or idea, we adopt the term *axial theme* because the broad scope of our work led to the identification of multiple such concepts, all interrelated. Axial themes are derived from thinking at a higher, more abstract level about the unifying aspects of underlying themes.
- *Model*–A *model* is an abstract construct which is derived by drawing inferences from themes and axial themes, their connections, and their implications. A model is intended to synthesize a broad picture of a given phenomenon, research question, or set of research questions. A good model is both descriptive of data already gathered as well as prescriptive in its ability to predict results of further inquiry.

All of these theoretical constructs are developed inductively and then tested and further refined through deductive application to further data and circumstances which fall within the scope of inquiry. Inductive development of a construct refers to the process of starting at a low level, reading qualitative responses and gradually deriving meaning through the constant comparative method. Deductive application means to apply constructs developed inductively to new data in a process which helps to understand this new data as well as to validate the constructs. [61]

To aid the reader, we will be careful in this dissertation to use the foregoing terms when referring to each such construct.

Chapter 2

Related Work

In this chapter we present work relevant to and informative of our current research. We divide related work into three groups:

- **Understanding computing in new contexts:** Our work is informed by methodologies found in this work and explores the context of computing in outdoor recreation
- **Envisioning the future of HCI:** Our work continues the HCI tradition of envisionment by presenting a future for HCI outdoors
- **Growing the HCI Outdoors research area:** Our work contributes to a foundation for HCI in outdoor recreation

In this chapter, where possible, we also characterize work by the Wobbrock Kientz contribution types, situating our work relative to existing work in HCI and HCI Outdoors and within a commonly accepted framework. Please not also that use of the word *theme* in these other works is close in spirit but not always precisely in line with our use of it in this dissertation.

2.1 Understanding Computing in New Contexts

Our work seeks to understand and explore the present and future of computing in hiking and other outdoor activities. Similar HCI work explores computing's impact in new contexts; in particular, contexts newly opened by mobile computing and/or contexts perceived as unfriendly. Such work often adopts an empirical or theory-building approach, and can often include qualitative, quantitative, and mixed-methods studies.

2.1.1 Computing at Mealtimes

Mealtimes are an example of a context whic is both newly opened and potentially unfriendly to computing. Moser et al. [62] explored attitudes about phone use during mealtimes. They described mealtime as a context with strong social and familial traditions. Meals offer reconnection time, a characteristic that is threatened by cell phone use. In an online survey with 1163 respondents, Moser et al. found attitudes towards cell phone use at mealtimes are affected by four factors: the age of the user, the age of the respondent, the respondent's own cell phone usage patterns, and the particular activities being engaged in by the cell phone user. They suggest design priorities to cater to these attitudes, such as social awareness features.

Ferdous et al. explored their *TableTalk* [27] system's ability to negotiate the tension between the social importance of togetherness and perceived distractions of screen-based computing during mealtimes. *TableTalk* uses individuals' devices to create a shared screen space on the table, with the intention of increasing mealtime interactions between participants. They found that *TableTalk* fostered togetherness and sharing of experiences during mealtimes, encouraging shared experiences between mealtime participants.

2.1.2 Computing in Active Outdoor Contexts

In a context closer to our own, HCI researchers have explored the impact and role of computing technology on movement-based activities. This work is generally intended to serve as empirical or, to some extent, theoretical contributions, to further understanding of users and their relationships with technology during outdoor physical activity.

Tholander et al. explored the experience of professional and amateur athletes (termed elite and recreational) [77]. In-depth interviews with 10 athletes focused on the athletes' experiences with heart rate and GPS devices in running and orienteering training. They found that athletes' responses indicate a notion of *measured performance* tied to data captured by their devices and a *lived* sense of performance based on their own mental and physical experience.

Desjardins et al. [25] explored the practice of using avalanche beacons for backcountry rescue, specifically the use of technological training grounds in order to acclimate skiers to beacon use in emergency situations. They highlight themes of team training and skill development, and provide guidance for designing such training grounds.

Knaving et al. [50] explored designing for "Advanced Amateur" runners—those who are not professionals or sponsored athletes but nonetheless actively participate in races [50]. Through analysis of data gathered using questionnaires and interviews coupled with design iteration, they present a set of five design themes for such athletes. Design themes, as described by these authors, are different from the use of the term *theme* in this dissertation, are a set of ideas or guidelines drawn from research which are intended to help designers think about how to design for a given group of people or circumstance. These themes include the following: *Festival*, *Togetherness*, *Practicalities*, *Competition*, and *Supporters*.

The approach and intended outcome of Knaving et al. is very similar to ours, however comparing their themes to known realities of hiking yields a poor fit. The *Festival* theme centers on races and the attendant festivities; the *Competition* theme is almost entirely absent from hiking; the *Supporters* theme focuses on loved ones who may support athletes in person or from afar; these themes simply do not fit into hiking. Our user group initially is all hikers, many of whom qualify as "advanced amateurs" if such a category existed for hiking. But unlike those sampled by Knaving et al. our users range in experience and enthusiasm from barely recreational all the way to sponsored athletes.

The foregoing work serves primarily as examples of the methodologies used in this dissertation. Each of these papers represents a different approach to creating knowledge within a research area, with approaches tailored to the contribution type of each piece of work. In our work to create knowledge and help to launch HCI Outdoors as a fledgling research area, we adopt various methodologies with various contribution types, as mentioned earlier.

In particular, our Phase 1 work is similar to Moser et al. [62], which takes an empirical approach and produces an empirical contribution, while our Phase 2 work is quite similar in approach and spirit to the envisionments described below. Knaving et al. [50] performed various research activities which, when triangulated, are similar to our own. However, our context and questions differ significantly from Knaving. This will necessarily lead to different results and understandings.

2.2 Past Envisionments in HCI

In seeking to develop our own vision for HCI Outdoors in Phase 2, we look to past HCI envisionments for inspiration and guidance. HCI has a long history of envisionment contributions–work seeking to describe a future for some aspect of computing. Indeed, many consider the 1945 Vannevar Bush essay *As We May Think* [16] to be an early work of HCI envisionment.

In this essay, Bush takes a broad look at scientific achievement in his time and in earlier decades, then begins to imagine a then-future world in which such progress continues and even accelerates. In particular, he imagines and outlines the future of the "scientific record," wherein humankind's accumulated knowledge of the world around us is stored and made available. Most interesting is his vision for a future memory extending machine, or "memex":

> A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory. –Bush, *As We May Think*

Bush describes this as a piece of furniture, in form like a normal desk, but augmented with machinery including magnetic tape storage, screens on the surface, a keyboard, and various levers for operating the device. Descriptions of the device's operation sound essentially like that of a modern PC, with certain aspects hinting towards our modern internet-connected

PCs as well. This manner of looking ahead to the future is core to HCI, and perhaps to computer science in general.

For our work, envisionments from Weiser [84], Ishii [33], and the less research-oriented but still important notions introduced by Krishna [56] provided inspiration. The envisionments by Weiser and Ishii gave rise to communities and movements within HCI, each with its own conference and research agenda - Ubiquitous Computing [2, 4, 7] and Tangible and Embedded Interaction [3, 6, 8], respectively. We discuss each here, along with other related ideas and inspirations.

2.2.1 Weiser: Ubiquitous Computing

Weiser's 1991 *Scientific American* article "The Computer for the 21st Century" envisions a future in which computers are all around us, being designed and used in a manner such that they become wholly unremarkable parts of our daily lives - we simply use them with little ceremony or concern. The primary aspect of this vision involves computing devices of three sizes: inch-scale *tabs*, foot-scale *pads* which are analogous to a sheet of digital paper, and yard-scale[1] *boards*. All devices interconnected and serve different purposes.

Interestingly, Weiser's vision has come to fruition in many ways. Mobile computing allows for nearly ubiquitous computer access and usage. Modern smartphones, tablets, smart TVs, and smart hub computers largely resemble the tabs, pads, and boards Weiser outlines.

In other ways, however, our modern relationship with computing is quite different from Weiser's vision. In particular, he outlines how *pads* are like "scrap computers," existing in large number and littering our desks and shelves similar to paper. While modern smartphones and tablets occupy a space somewhere between Weiser's tabs and pads in size and shape, in usage they are far removed. Devices are treated as valuable property, carefully preserved and customized with cases and screen protectors. They are considered to be deeply personal objects.

[1] "Yard" here indicating the Imperial measurement - 3 feet or 36 inches.

Our modern use of computers is routine enough to be considered unremarkable. In some sense this is similar to Weiser's vision, but the actual software used is less ignorable. In an age where many companies derive their primary income from advertising, apps are often designed to capture and keep users' attention.

However, we take inspiration from Weiser's vision of computing; in particular Weiser's notion that if done correctly, computing may have the ability to "disappear," leading to a situation where "using a computer [is] as refreshing as taking a walk in the woods." [84]

2.2.2 Krishna: No-UI

The No-UI movement, as described by Krishna in the book *The Best Interface is No Interface* [56], responds to the way mobile technology dominates modern users' time and attention. Krisha how this happens and the intentionality behind much of it while calling for a different approach.

In a No-UI approach to computing interaction, computers are able to act for our benefit without user interaction. An example from the book highlights a "sophisticated" mobile app requiring 17 individual steps to unlock a car. Krishna's proposed No-UI alternative simply uses wireless technology to sense when the owner is near the car, and unlocks the car automatically as the owne.

Such an approach is of interest when designing technology for outdoor recreation and other active pursuits where attention and user interaction are in short supply. Further, a No-UI approach prioritizes focus on external activities rather than on computing devices. The No-UI approach informs our vision development in Phase 2 of this work.

2.2.3 Ishii: Tangible Bits/TEI

In his paper *Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms* [33], Ishii presents another vision of future computing. In Ishii's vision, computing is integrated into the physical world and interactions with objects in the physical world cause things to happen in the digital world. Meaningful communication between computers and humans moves between the periphery and the center of attention. This focus on the physical world is a great fit for HCI Outdoors.

Ishii points to “the aesthetics and rich affordances of...historical scientific instruments” as a major inspiration for his vision. We also draw inspiration from the large and varied array of gear that already exists for hiking. Such existing gear provides an excellent platform for including computing in hiking as well as for considering interesting and helpful roles for computing to play in hiking.

Further, we seek to incorporate Ishii’s notion of computing at the periphery of human experience. Such a design approach fits nicely with Krishna’s No-UI principles and our goal of allowing computing to enhance, enable, and encourage hiking and other recreation activities without being intrusive.

2.3 Existing Work in HCI Outdoors

There is a growing body of work which can be characterized as HCI Outdoors. This area encompasses a broad swath of HCI research, inclusive of any application of computing in an outdoor setting. Much of the work in this area involves the design, building, and testing of new systems for use in particular outdoor activities. We briefly discuss application of computing to specific types of outdoor recreation, exploration of computing’s place in certain of these activities, and efforts to build community within HCI Outdoors.

2.3.1 Exploring Specific Applications

Wobbrock and Kientz stated, “HCI is driven by the creation and realization of interactive artifacts.” An important area of research in HCI Outdoors builds and tests systems that will better inform our basic understanding of technologys role in outdoor recreation.

We provide a brief survey of some of this artifact-driven work, organized by the roles which computing plays in each piece of work. Our own artifact-driven work includes an envisionment for the future of computing in outdoor recreation.

Assessment and Instruction

Assessment and instruction are popular areas for research in various outdoor activities. Jensen explored *Football Lab*, an automated trainer for soccer [36]. Hasegawa used sound to encourage proper skiing form [32]. Ladha implemented *ClimbAX* [57], a system assessing climbers' skill levels. Mencarini [60] explored the emotions experienced by climbers, suggesting haptic feedback from a partner could help manage moments of distress while learning to climb.

Safety and Navigation

Safety and navigation also enjoy a good deal of research focus. Cycling is a particularly popular area of exploration. Pielot explored the notion of "spontaneous navigation" for somewhat less-structured cycling trips with *Tacticycle* [70]. Carton presented a bicycle and motorcycle glove that can signal turns, stops, or frustrations [17]. Dancu exploresdboth signaling and navigation with *GestureBike* [22]. More directly related to safety, Yoshida presented a system for detecting and avoiding collisions between pedestrians and cyclists [87], while Walmink [82] and Jones [38] explore augmenting helmets for purposes beyond safety.

Reflection and Motivation

Others explore reflection on activity, such as Khot's SweatAtoms [45], TastyBeats [46] and EdiPulse [47]. Stusak also explores reflection and motivation with physical representations of running activity with *Activity Sculptures* [75]. De Oliveira [24] and Nguyen [68] explore novel applications of technology for motivation and encouragement.

Social Aspects

Researchers also explore computing's ability to foster social engagement in exertion and recreation activities. In Mueller's work, participants ran with a quadcopter companion [64]. Mueller also explored running together with a friend over a distance [65]. Curmi explored sharing athletes' heart rates over social networks, allowing friends and family to provide feedback during races [20]. In addition to previous work with helmets cited above, Walmink also explored sharing heart rates on the back of cyclists' helmets [81].

Augmentation

In something of a departure from approaches where computing fills an existing role, some researchers explore augmenting existing activities in new ways. With *SkiAR* [26], Fedosov introduced an augmented reality (AR) system for sharing personalized maps of ski slopes between skiers. Kim demonstrated an AR approach to tennis coaching [48]. Kajastila created a new climbing experience by projecting graphics onto a climbing wall [42].

Sensing and Notification

Rather than applications of technology to specific activities, some researchers explore how different sensing or notification methods function within the context of exertion and outdoor activities. Kosmalla explored sensing for automatic climbing route recognition with *ClimbSense* [52], and notification methods with *ClimbAware* [53]. Pakkanen explored haptic feedback for cycling [69]. Jones explored recognition of ski turns [39].

2.3.2 A Broad Snapshot of Recent Work

We close our section on related work in HCI Outdoors with a broad snapshot of prior work from the CHI 2018 Workshop on HCI Outdoors [41]. Selected papers from this workshop provide a picture of current thinking and the state of the field. We present broad categories of work which was presented and position our work relative to the work presented there.

Other workshops have been held on this topic such as NatureCHI events at CHI and MobileHCI [30, 31], the UbiMount workshops at UbiComp [1, 21], and the HCI Outdoors SIG meeting [40, 41].

Children Outdoors

Work in this area explores the intersection of not only HCI and the Outdoors, but specifically HCI Outdoors and children. Samariya et al. [72] discuss the ways in which the motivations, interests, and approach to the outdoors differ between children and adults, and share projects and project ideas seeking to encourage children's wonder towards and engagement with the natural world. In work which also relates to the *Public Spaces* theme discussed below, Richardson et al. [71] sought to leverage the historical and communal aspects of shared spaces such as local parks in order to foster community and encourage learning. Preliminary work included development of an app allowing individuals to explore and learn more about the historical features of a local park. Richardson et al. noted the approaches and interests of those who used the app including the children, the children's teachers, and the park rangers.

Designs Sensitive to Outdoor Activities/Use

Others have sought to understand and explore the ways in which computing and other technology can be responsive to the unique and varied ideas, attitudes, and approaches to the outdoors. Kotut et al. [55] explored the potential for tension between various groups of trail users, focusing in particular on groups identified as *Families, Farmers, Guide-Book Authors, Mental/Physical Rehab, Scientists, Search and Rescue Workers, Solo Hikers*, and Tourists. They used affinity diagramming to explore tensions between these groups; once mapped, they explored how technology could play a role in mitigating or building tension between these groups. They conclude that understanding these tensions can help foster community on the trail. Cheverst et al. [19] explored the ways in which technology allows for the "subdual" of the natural world, how new technologies are often initially mistrusted and considered unfair within outdoor recreation before eventual adoption, and how this relates to current and future growth within HCI Outdoors.

Public Spaces

Certain work within HCI Outdoors seeks to explore outdoor spaces which are closer to home. Jaakkola et al. [34] observed individuals' interactions with the natural world in city parks in Berlin, with intent to understand how individuals interact with such spaces. de Aguiar et al. [23] detailed the inspiration and motivation, design, and in-process realization of EnAct, an outdoor installation intended to explore the future of interaction with outdoor "cyber-physical" environments. They outlined future to install their design in an "under-used" public space and conduct a user study on its interactions.

Supporting/Understanding Communication

Computing, and in particular mobile technology is often a means of communication. The "great outdoors" provides a particularly interesting area of study for advancing communication technologies. Jones et al. [37] presents past and current work in leveraging modern communication technologies in support of collaborative work. In particular, they present efforts at supporting wilderness search and rescue through the means of videoconferencing and other technologies, with an aim towards increasing collaboration and coordination between searchers. Bartolome et al. [13] describe the use of an extremely popular modern communication medium—Twitter—in understanding the various concerns, interests, foci, and goals of groups they term "hiking cultures." They argue that there are various ways of understanding these cultures, and that doing so is important in approaching HCI design for their use. Our work is not specifically focused on communication while hiking, but important themes related to communication emerged from our studies and appear in the computing artifacts we created to realize our vision.

Supporting Non-Recreational Activities

Certain research within HCI Outdoors ventures even farther afield. Scott [73] explores the unique challenges and needs of farmers who increasingly seek to use computing in order to maximize their ability to raise and harvest crops and animals. Stelter and McCrickard [74] expand possibilities for citizen science enabled by increasing access to and decreasing cost of mobile technology.

Within Wobbrock and Kientz' framework [86], the workshop papers presented here represent a variety of contribution types; particularly focusing on *artifact, empirical*, and *theoretical* contributions. Our work embraces all of these as contributing towards a larger whole.

2.4 Conclusion

Our approach to HCI Outdoors is informed and inspired by the work presented here. We seek to build on this work and learn from it in ways that will lead to a better understanding and the design of better systems.

Our work complements existing work nicely. Existing HCI Outdoors work is lacking in terms of envisionment and theoretical contributions, both of which are important portions of our work.

Chapter 3

Phase 1: Quantitative Survey

Phase 1 of our work focused on the present state of technology use while hiking. In this phase and its parts, we sought to understand hikers' attitudes towards and practices regarding hiking and technology use when hiking. Understanding users and their needs and practices can lead to positive outcomes including further questions for exploration and better designs.

In Phase 1, we adopted an *explanatory sequential* study design. This is a mixed-methods design in which initial quantitative inquiry informs further qualitative work. Quantitative methods paint a broad picture of the *what* of a given set of research questions or user population. Qualitative methods then help to deepen and give nuance, answering the *how* and *why* [61].

The work presented in this chapter represents the quantitative portion of our explanatory sequential study design. The primary result of this work was a broad understanding of hikers' preferences with regards to both hiking and technology, including groups of hikers based on preference, correlations between preferences, demographic differences in preference, and other components. We also uncovered questions for deeper exploration through qualitative work.

We conducted a survey of individuals across the United States. Surveys gather a large amount of data at a relatively low financial and labor cost. They also allow one to gather "an overview, or a 'snapshot' of a user population" [58]. However, surveys also have drawbacks including recall bias, a phenomenon in which questions such as "How often do you hike?" lead to data which may not be factually accurate due to the fallibility of participants' memories. Our study design sought to correct for this and other potential pitfalls.

This chapter makes an *empirical* contribution. These contributions are evaluated based on the soundness of the data gathering methods employed and the importance of the results gathered [86].

3.1 Methodology

Our quantitative survey was conducted in May 2017. The survey gathered information about hikers' preferences with regards to both hiking and technology use while hiking. To this end, the first portion of the survey focused on hiking, while a second portion focused on technology use while hiking.

Surveys must be carefully designed in order to gather reliable data. Our survey design followed guidance from in Lazar et al. [58, pp. 99-124]. This included: determining a target population and sample size, question design, pre-testing of the survey instrument, and deciding between online and paper delivery. Our decisions regarding these issues are summarized in the paragraphs below.

We intentionally selected a broad population—adults in the United States—in order to gather a broad dataset. We considered limiting our sample to self-identified hikers; however, we determined that individuals who do not identify as hikers may still hike occasionaly. These indivuduals, we reasoned, may provide meaningful data based on their experiences. Our approach follows a probabilistic sampling method, wherein a smaller sample is selected from among a much larger population [58].

Careful survey instrument design is an important step in gathering valid data. Consideration include: question content and wording, the number and type of questions to ask, and the ordering of questions. We considered each of these through several design iterations. Our survey design was then pre-tested twice with small numbers of respondents. Pre-testing served to reveal areas for improvement, including unclear wording of questions or instructions, poor question ordering or grouping, and the addition or removal of questions or options.

Questions about hiking were designed to explore constructs relating to hiking frequency, location, companionship, motivations, duration, and difficulty. Questions use a 5-point Likert scale. In order to avoid recall bias, questions were phrased to measure preference rather than practice. We also included a "weeder question" designed to assess participants' attention level and allow for easy identification and removal of invalid data.

Technology questions were also phrased to focus on preferences rather than practice. Because a cell phone or smartphone is a nearly ubiquitous piece of technology in modern times, we asked separately, "Do you prefer to bring a cell phone or smartphone when hiking?" This was followed by a list of other technology items, and individuals were asked to check each item they prefer to bring when hiking. Asking about mobile phones separately allowed participants to consider this particular item specifically and primed them for the list of other items to follow.

Participants were recruited via Amazon Mechanical Turk, an online crowdsourcing platform[1]. We chose online recruitment because it allowed for responses from a broad swath of individuals from various demographics across the United States. It is also simple to set up and inexpensive in terms of material and labor costs. More traditional paper-based sampling, by contrast, requires finding respondents and their addresses, preparing and mailing surveys, waiting for responses, and manually entering responses.

Qualtrics[2] survey software was used in administering the surveys. Qualtrics is a popular online survey platform that offers flexibility in designing and carrying out surveys. This allowed us to carefully structure our survey to measure the constructs we identified. Participants were linked to the Qualtrics survey from the MTurk HIT. MTurk provides facility for linking to Qualtrics and collects a finished survey code from participants when they finish.

[1]https://www.mturk.com/

[2]See www.qualtrics.com

We gathered a total of 1042 responses. 40 of these were eliminated due to not completing the survey, failure to answer the attention question correctly, or other data integrity issues for a total of 1002 valid responses. Respondents ranged in age from 18 to 76 (mean: 34.94, median: 32, sd: 10.95). 579 respondents were male and 423 were female. Respondents reported 916 unique United States ZIP codes. Participants were compensated $0.50 and took an average of 2 minutes, 42 seconds to complete the survey.

3.1.1 Amazon Mechanical Turk

Buhrmester et al. [14] found in 2011 that data collected via Mechanical Turk are "at least as reliable as those obtained via traditional methods." We carefully considered known limitations of Mechanical Turk, such as inattention and boredom, and sought to minimize potential problems in our study design. This included using Mechanical Turk tools to recruit from the correct geographic region, an attention question in the survey, and careful post-analysis of responses in order to find and discard obvious bad data.

In a 2018 follow-up paper by Buhrmester et al. [15], the authors summarize guidelines and best practices as discovered by researchers over time in using Amazon Mechanical Turk. In brief, they outline three main concerns that should be addressed in a study which seeks to use Mechanical Turk as a means of recruitment:

- **Inattention:** The authors recommend carefully-worded and clear instructions in order to avoid participant confusion. Our study designs underwent several iterations with three researchers carefully considering question content and number of questions, as well as instruction content and wording. We also conducted pilot runs of each study prior to their going "live." The authors also mention the use of attention questions, or questions which are intended to break the flow of the survey and test whether individuals are paying attention to their answers. Our surveys included attention questions.
- **Nonnaiveté and Dishonesty:** Since Mechanical Turk's internal tools prevent workers from requesting payment for the same HIT (human intelligence task) more than once,

the main concern here is that individuals may have already particpated in similar studies or been exposed to common stimuli used in other studies. Due to the relatively niche nature of our work, and based on our literature search as previously outlined, we did not find this to be a concern for our data gathering via MTurk.

- **Attrition:** This aspect is concerned with both individuals who drop out during an individual HIT as well as those who drop out in-between multiple surveys in a study. Our studies were all single-survey, which sidestepped any type of between-instruments attrition. As for attrition by participants during a single HIT, we found that our numbers were very low (less than 1% for quantitative survey, less than 3% for qualitative).

3.2 Clustering

A goal of our quantitative survey was to attempt to determine clusters or groups of hikers based on preferences. We clustered the hiking data using K-Means clustering. This was done using the K-Means tool from the WEKA data analysis package[3].

We tested values of k ranging from 2 to 10. We settled on $k = 5$ because it provided groups that were cohesive and strongly differentiated from one another. This process was repeated for technology preferences, where we also settled on $k = 5$.

We clustered hiking and technology data separately, anticipating that there might be interesting correlations between membership in hiking and technology clusters. We attempted to generate clusters with a combined dataset of both hiking and technology data. Clusters generated with this dataset did not provide useful insights regarding the data.

3.2.1 Hiking Clusters

Figure 3.1 is a radial chart of the five hiking clusters. Values plotted in the chart correspond to average values on a per-cluster and per-question basis, with 1 representing "Strongly Disagree" and 5 "Strongly Agree" on a 5-point Likert scale. For instance, "Alone" corresponds to the

[3]https://www.cs.waikato.ac.nz/ml/weka/

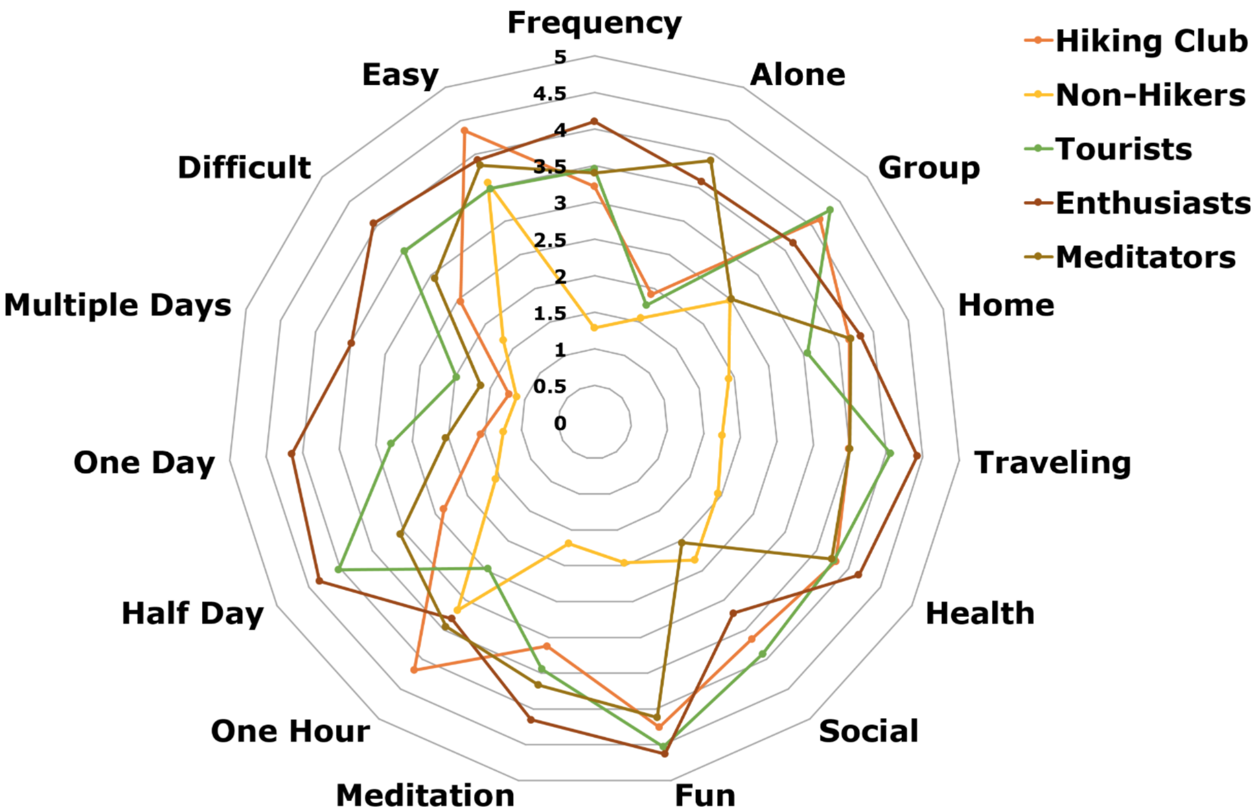


Figure 3.1: Five clusters of hikers identified by k-means clustering.

question, "I prefer to hike alone." The exception to this is "Frequency," where 1 corresponds to "Never" and 5 corresponds to "Once a week."

In an effort to think deeply about and lend color to these clusters and their overall preferences, we gave each a title and a brief characterization as follows (with percentages representing cluster size relative to the overall sample size):

- **Cluster 1—*Hiking Club* (26%):** Members of this group prefer short and easy hikes roughly once a month. No motivation stands out in particular for this group but as a group they scored meditation lower than other groups (other than the non-hikers).
- **Cluster 2—*Non-Hikers* (5%):** Members of this group prefer not to hike often—perhaps even not at all—and prefer hikes that are short and easy if they do go hiking. They are more motivated by social interaction than by other motivations.

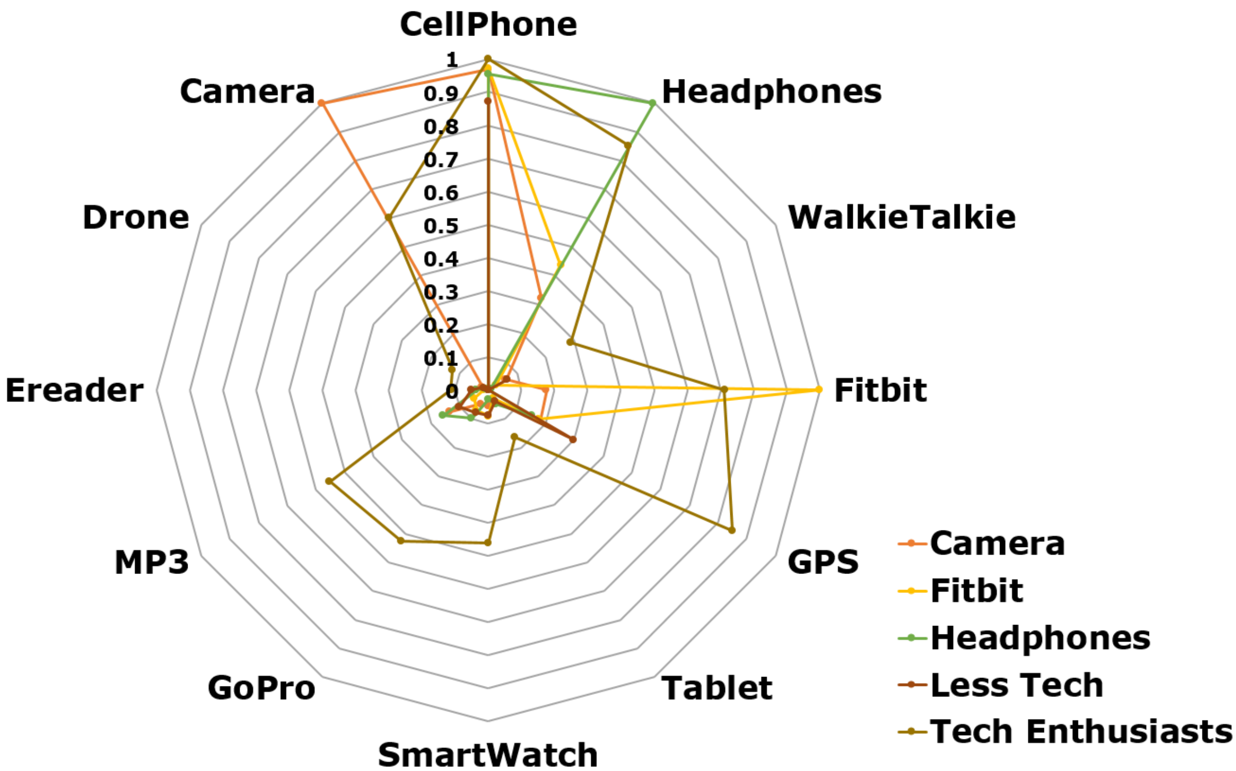


Figure 3.2: Five clusters of technology preferences identified by k-means clustering.

- **Cluster 3—*Tourists* (25%):** Members of this group enjoy hiking away from home. They prefer to hike in a group much more than hiking alone, and strongly prefer hikes that last half a day.

- **Cluster 4—*Hiking Enthusiasts* (25%):** Members of this group enjoy hikes of all lengths and difficulties. They enjoy hiking at home or while traveling. They are less motivated by social interaction than *Tourists* or *Hiking Club*.

- **Cluster 5—*Meditators* (18%):** Members of this group enjoy taking frequent hour to half-day hikes. This is the only cluster which prefers hiking alone over hiking in a group. Health and meditation are the strongest motivators for these individuals.

Of note here is the similarity between clusters, apart from the *Non-Hikers*, with regards to "fun" as a motivation for hiking. It appears that although motivations tend to vary from one cluster to another, all hikers consider hiking a fun activity and are motivated by this consideration. Interesting follow-up research could probe what particular aspects of hiking are considered fun by different individuals or groups, and potentially increase outdoor participation by maximizing these factors.

3.2.2 Technology Clusters

Figure 3.2 shows a radial chart plotting mean response values to questions about technology preferences. In this case, data points represent mean values ranging from 0 to 1, with 1 meaning that all individuals in a cluster prefer to bring that particular item and 0 none.

In examining technology clusters it can be seen that 3 of 5 groups (*Camera, Headphones,* and *Fitbit*) are characterized by a strong preference for bringing their cell phone and one other device. The fourth group, *Less Tech* tends to prefer to bring only their cell phone and the last group prefers to bring any of a multitude of devices, each with varying likelihood. Each cluster besides *Less Tech* also displays some probability of bringing headphones. The *Less Tech* displays an elevated probability of preferring to carry a non-phone GPS device as compared to other clusters besides *Tech Enthusiasts.*

3.3 Device Frequency and Number of Devices

Device	Percentage Who Prefer to Carry
Cell Phone	95.0%
Headphones	51.5%
Camera	36.0%
Fitbit/Activity Tracker	25.4%
GPS	24.7%
GoPro/Action Camera	10.9%
Smartwatch	8.5%
Radio/Walkie Talkie	6.2%

Table 3.1: Devices in our quantitative survey and percentages of participants who indicated a preference to carry each device when hiking. Other devices were selected by less than 5% of participants.

Table 3.1 displays devices in our survey which were selected by more than 5% of participants. Of the top few devices, headphones, camera, and Fitbit each had clusters whose primary distinction was individuals' preference for a cell phone and that item, while GPS did not.

Number of Devices	Percentage of Participants
0	1.5%
1	1.8%
2	46.0%
3	25.4%
4	14.3%
5	5.6%
6	3.2%
7	0.9%
8	0.7%

Table 3.2: Number of devices selected by participants in our quantitative survey, and the percentage of participants who selected each number.

We also examined the number of devices individuals choose to carry. Table 3.2 displays this data. Summing the four most popular numbers of preferred devices—2-5 devices—accounts for 91.3% of individuals in our survey. This may indicate that individuals would be open to carrying more devices in the future, provided they contributed positively to the hiking experience.

3.4 Exploring Correlations

We sought to find other interesting insights about hiking and technology preferences, particularly as they relate to each other and to the demographic data we collected. We created contingency tables and used chi-square (χ^2) tests in order to determine what effect hiking or technology cluster membership and demographic differences might have on preferences.

While chi-square was appropriate for many of the tests we ran, some contingency tables had cells with expected values less than 5, which is the cutoff for using a chi-square test. In these cases, we used Fisher's Exact Test. Because we were running several post-hoc tests, we used the Benjamini-Hochberg correction in order to calculate new α values. Table 3.3 lists each contingency table along with corresponding information.

Table	Method Used	P-Value	Adjusted α	Statistically Significant
Age/Tech Cluster	Fisher's	$5.0e-04$	0.0235	Y
Hiking Cluster/Tech Cluster	Fisher's	0.00599	0.0294	Y
Age/Hiking Cluster	Fisher's	0.0295	0.0353	Y
Region/Hiking Cluster	Fisher's	0.0475	0.0382	N
Age/Number of Devices	Fisher's	0.293	0.0471	N
Region/Tech Cluster	χ^2	0.847	0.05	N

Table 3.3: χ^2/Fisher's results for contingency tables.

As can be seen from examining results in the table, one's age is likely to correlate with both the technology cluster and the hiking cluster one belongs to. Further, one's hiking preferences appear to correlate with their technology preferences.

Figures 3.3-3.5 display χ^2 residuals for the three statistically significant differences displayed in Table 3.3. In these plots, blue represents positive correlation while red represents negative, and larger squares represent stronger correlations. Plots for the other residuals listed in Table 3.3 appear in Appendix A.

In examining the Age/Technology Cluster residuals in Figure 3.3, it appears that much of the variance is due to different ideas about headphones when hiking. The *Headphones* tech cluster is strongly correlated with younger age brackets, while age brackets above 35 are less likely to be in this cluster. Other points of interest include the correlation between the *Fitbit* cluster and the 35-44 age bracket and the corresponding negative correlation with the 18-24 bracket. This youngest age bracket is also negatively correlated with the *Less-Tech* cluster. Meanwhile, the *Camera* cluster appears to be clearly correlated with ages 45-64.

Age/Hiking Cluster (Figure 3.4) displays an interesting trend. Younger age brackets tend to show less differentiation with regards to their hiking cluster membership. This

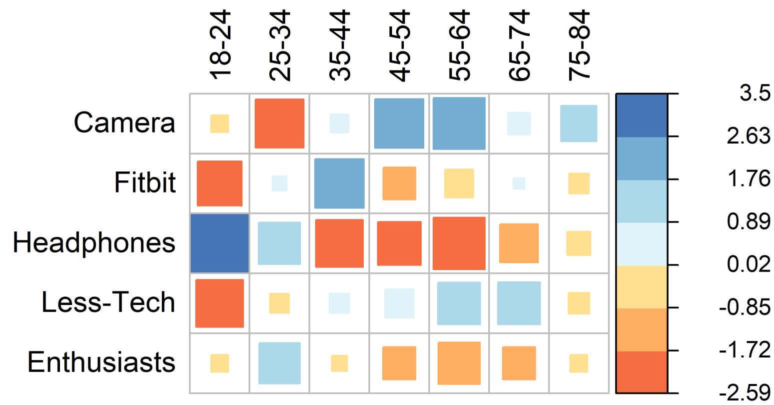


Figure 3.3: χ^2 residuals for the Age/Technology cluster contingency table. Cameras and headphones are a primary factor in differentiating between age groups.

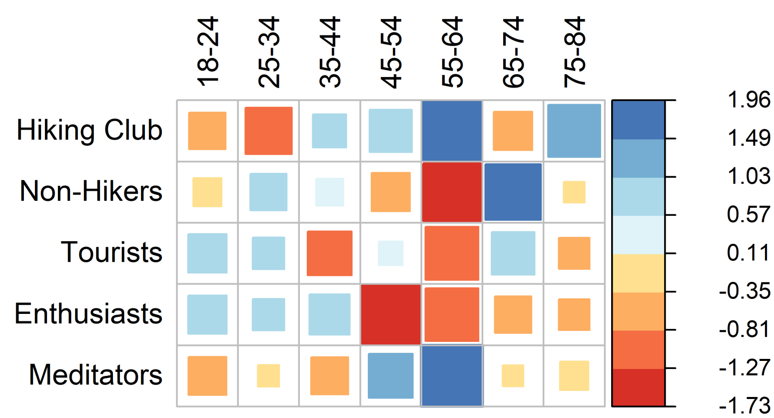


Figure 3.4: χ^2 residuals for the Age/Hiking Cluster contingency table. The most differentiation is found in the 55-64 age group but the correlations are not as strong as other comparisons.

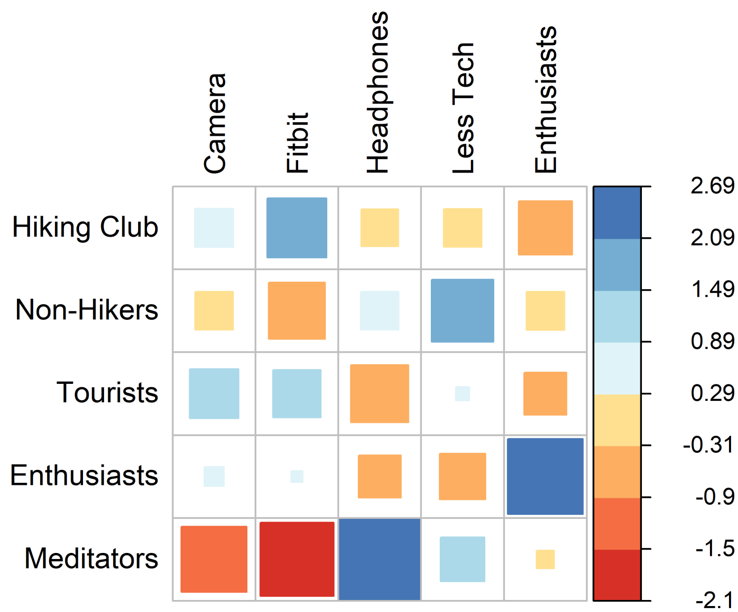


Figure 3.5: χ^2 residuals for the Hiking Cluster/Technology Cluster contingency table. As might be expected, meditators tend to prefer to hike with headphones.

differentiation grows stronger with each age bracket, peaking at the 55-64 (n=58) age bracket, which is strongly correlated with the *Hiking Club* and *Meditators* clusters, and negatively correlated with the others, particularly *Non-Hikers*. Also of note is a fairly strong negative correlation between *Enthusiasts* and the 45-54 age bracket, and a correlation between *Non-Hikers* and 65-74. Notable negative correlations also exist between the *Hiking Club* cluster and the 25-34 age bracket, and *Tourists* with 35-44. These correlations are not as strong as the correlations shown in Figure 3.4 as indicated by the scale on the right side of each figure.

Looking at the Hiking Cluster/Technology Cluster residuals in Figure 3.5, we note that *Meditators* are correlated with *Headphones*, and negatively correlated with both *Camera* and *Fitbit*. *Enthusiasts* are likely to be enthusiastic about both hiking and technology, while lack of enthusiasm for both is similarly apparent in the *Non-Hikers* and *Less Tech* clusters. *Tourists* are more likely to belong to *Camera* and *Fitbit* clusters and less likely to be in *Headphones*. Finally, *Hiking Club* cluster members are more likely on average to be in the *Fitbit* technology cluster.

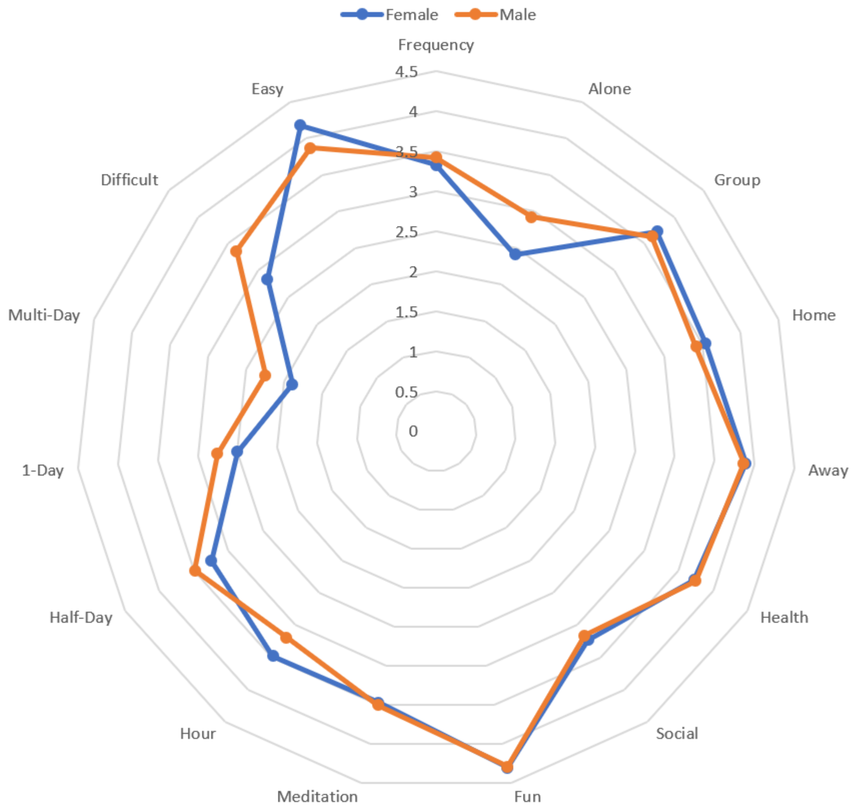


Figure 3.6: Overall mean values for hiking preferences separated by gender. Women prefer not to hike alone and men report a preference for more difficult hikes.

We note also that region appears to have no measurable effect at this sample size on one's hiking or technology preferences, and that no apparent correlation exists between age and the number of devices selected by participants.

3.5 Differences in Preference by Gender

An initial application of χ^2 testing to contingency tables for Gender/Hiking Cluster and Gender/Technology Cluster led us to further explore differences in preference between genders. Figure 3.6 shows overall means for hiking preferences when separated by gender. Interesting differences in preferences are readily apparent as it relates to hiking alone, hiking duration, and hike difficulty. In order to determine whether these differences were statistically significant, we ran χ^2 tests on gender and specific preference questions, as well as tests on overall results

Table	Method Used	P-Value	Adjusted α	Statistically Significant
Gender/Technology Cluster	χ^2	$1.42e-08$	0.00294	Y
Gender/Easy Hikes	χ^2	$1.90e-08$	0.00588	Y
Gender/Difficult Hikes	χ^2	$3.87e-08$	0.00882	Y
Gender/Hike Alone	χ^2	$7.44e-08$	0.0118	Y
Gender/Hiking Cluster	χ^2	$2.2e-06$	0.0147	Y
Gender/Multi-Day Hikes	χ^2	$2.28e-06$	0.0176	Y
Gender/Half-Day Hikes	χ^2	$3.46e-04$	0.0206	Y
Gender/Hiking in a Group	χ^2	$9.60e-04$	0.0265	Y
Gender/1-Hour Hikes	χ^2	0.0175	0.0324	Y
Gender/Number of Devices	Fisher's	0.102	0.0412	N
Gender/Full Day Hikes	χ^2	0.106	0.0441	N

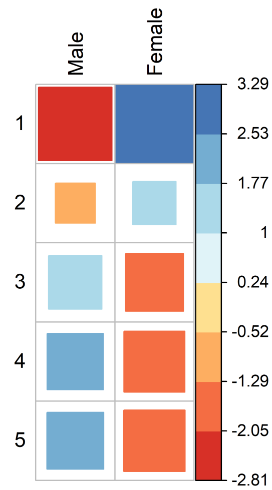
Table 3.4: χ^2/Fisher's results for contingency tables involving gender.

such as Hiking and Technology clusters, and number of devices. Results of these can be seen in Table 3.4.

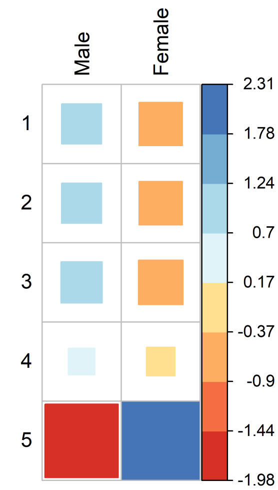
Gender appears to be a strong differentiator in certain aspects of preference. Figure 3.7 shows χ^2 residuals for Gender/Hiking Alone, Gender/1-Hour hikes, Gender/Tech Cluster, and Gender/Hiking Cluster. Numbers 1-5 in the tables represent Likert items, with 1 corresponding to "Strongly Disagree" and 5 corresponding to "Strongly Agree." Further plots of residuals which are in Table 3.4 can be seen in Appendix A.

In general, female respondents are correlated with a preference for shorter, easier hikes while males tend to be more likely to prefer longer and more difficult hikes. Men are also more likely to prefer hiking alone. These differences appear to correlate with technology cluster differences, where males are more likely to be in the *Headphones* cluster which is in turn correlated with the *Meditators* hiking cluster, while women are more likely to be in *Camera* and *Fitbit* clusters, which are correlated with the *Hiking Club* hiking cluster.

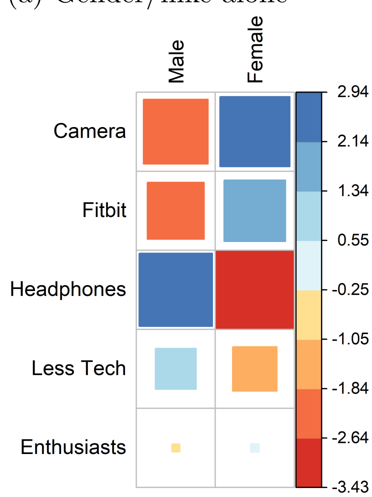
Also of note are what appear to be strong similarities between genders as it relates to hiking frequency, location, and motivations. Also, though hiking alone is strongly differentiated, hiking in a group is not.



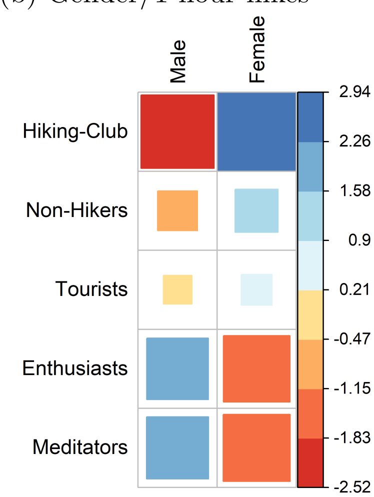
(a) Gender/hike alone



(b) Gender/1 hour hikes



(c) Gender/Technology clusters



(d) Gender/Hiking cluster

Figure 3.7: χ^2 residuals for contingency tables relating gender to certain factors. Additional results can be found in Appendix A.

3.6 Discussion

Several interesting results described in the previous section arise from our quantitative inquiry. We conclude by discussing how each result integrates with prior work and present implications for future work.

3.6.1 95% Of Individuals Prefer to Carry a Phone Hiking

At first blush, one might expect that individuals would often not want to carry a cell phone or smartphone when hiking. Reasons for this include:

- Likely lack of coverage
- Concerns about damaging an expensive smartphone
- Potential for distraction from texts, calls, and other notifications
- A cell phone may serve as a general reminder of daily life during an activity that is intended as a means of getting away

With this in mind, our anticipation was that some number of individuals would prefer to carry a phone when hiking, but also that many would choose to leave their phone at home. Thus we were quite surprised by the sheer number of individuals—19 in every 20—who indicated a preference for hiking with ther phone.

Questions naturally arise from this, including: why do so many individuals prefer to carry a phone when hiking? What do they use them for, if at all? Answers to these questions may include that individuals carry a cell phone either for real or perceived safety benefits, or to use a specific app, or simply for communication. Our qualitative work in the next phase of the study seeks, in part, to answer these questions.

3.6.2 Clusters

Quantitative data gathered through our online survey paints a broad picture of the variations in preferences between individuals. Our clustering of the data highlights the ways in which these preferences reveal differences and similarities between groups of individuals.

Our χ^2 testing also illuminates some of the interplay between these preferences, in particular correlations between particular hiking and technology preferences. This seems to confirm our initial assumptions that hiking preferences may influence technology use preferences, but reveals little about these correlations or what drives them. Our qualitative work, in particular interviews, sought to understand more deeply the relationship between individuals' hiking preferences and their preferences toward, and use of, interactive computing while hiking. This work is detailed in Chapters 4 and 5.

3.6.3 What People Carry

Our quantitative work revealed which devices people prefer to carry when hiking, how many prefer to carry different devices, and how many devices individuals choose to carry.

As discussed, a cell phone or smartphone is the most commonly preferred item, selected by 95% of participants. Data from the Pew Research Center shows that in January 2018, 95% of adults in the United States reported owning a cell phone, with 77% of all adults surveyed reporting owning a smartphone [5]. Although the parity between percentages here—95% in both our survey and in the Pew survey—is interesting, we do not simply assume that individuals in our survey who indicated they did not prefer to carry a phone when hiking did so because they do not own a cell phone.

Because of our approach, which sought for breadth overall, we did not differentiate between smartphones and non-smartphones in our survey. Thus while the percentages of smartphone versus non-smartphone cell phones used by our survey respondents may reasonably be assumed to be in line with those reported by Pew, we simply do not know. It is worth further investigation into what these percentages are, because usage differs greatly between smartphones and non-smartphones.

It is interesting that the number of individuals who selected headphones is so high at 51.5%. This is especially so given that in general many individuals indicated that they prefer to hike in a group, and far fewer indicated a preference for hiking alone. Of note here is the fact that there is a strong correlation between the *Meditators* hiking cluster, who prefer to hike alone more so than in a group, and the *Headphones* technology cluster. This likely indicates that at least some portion of the headphone usage is meant as a means of social isolation during a hike. However, we may also surmise that there are likely many other reasons and uses for headphones when hiking. We explored these in our qualitative work, detailed in Chapters 4 and 5.

Clear next steps here involve understanding reasons for carrying and uses of these devices on the trail. Many of the devices in our survey are devices which are single- or near single-purpose. This includes a camera, activity tracker, action camera, and others. Further inquiry into reasons for bringing these devices or specific uses of these devices on the trail may not lead to very interesting results. However, a smartphone and headphones may be used for many different reasons. The smartphone in particular can be used for a remarkably wide variety of purposes. Further, carrying a GPS device apart from the built-in GPS of a smartphone is also an interesting use case to explore. Our qualitative inquiry also attempts to shed light on these areas.

3.6.4 Correlations

A number of interesting correlations were found in our χ^2 testing. These include correlations between hiking and technology clusters and those based on demographic data. We attempt to contextualize these correlations and to examine them in the light of their ability to drive future inquiry.

In examining the Age/Tech Cluster table, we note that young people are strongly correlated with the *Headphones* cluster. This may be an extension of a preference for headphone usage in day-to-day life, or it may be a difference in their approach to outdoor experiences. While our qualitative inquiry does give some insight into the particular *usages* and *reasons* for using headphones on-trail, we presently do not have an understanding of the reasons for this youth-centered preference for headphones. This is an interesting area for further study.

Similarly, other age-based correlations may be interesting points for further study:

- Why are individuals between 35-44 correlated with the *Fitbit* cluster?

- Why are older individuals correlated with the *Camera* group?

Also interesting are areas where correlation is lacking. For instance, although terrain and hiking circumstances vary widely across the United States, region was not correlated with differences in either hiking or technology preferences. Further study may be able to tease out what factors lead to this homogeneity, and to determine whether there are areas in which these preferences do vary regionally.

The correlations which center around gender also present an interesting set of considerations. In particular, female respondents were more likely to prefer easy hikes, shorter hikes, and hiking in groups, and less likely to prefer longer hikes or hiking alone. Gender, however, did not differentiate with regards to preferences surrounding hiking frequency, location, or motivations. These preferences relate to more ephemeral aspects of one's approach to hiking—how often one wants to hike, and what motivates them to do so—while those which show differentiation are related to more concrete aspects. It seems a reasonable hypothesis that safety may be a factor in these differences. Further study may help to shed light on this and lead to further insights.

Also of note, many of the correlations seem to point to internal consistency within our data. For instance, the *Hiking Club* cluster is a group of individuals for whom hiking is a regular practice, often motivated by fitness. This cluster is most highly correlated with the *Fitbit* tech cluster, which does not seem coincidental. The *Meditators* hiking cluster, individuals who prefer largely to hike alone and for meditation, are strongly correlated with the *Headphones* tech cluster (headphones being a means of social isolation), and negatively correlated with the *Fitbit* cluster. We find these observations meaningful in that they serve to uphold the validity and meaningfulness of our results.

3.6.5 Conclusion

Through quantitative inquiry, we gained a broad understanding of individuals' hiking and technology use preferences. Survey results indicated that the vast majority of individuals prefer to carry a phone when hiking, although they may prove distracting and may not always have coverage. This leads to questions regarding intended purposes and uses for phones on the trail, which are explored through qualitative inquiry, detailed in Chapters 4 and 5.

Further examination also led to the identification of correlations, including some based on demographics and some based on membership in identified hiking clusters. Particularly interesting are correlations between hiking preferences and technology preferences, which are also explored through quantitative inquiry. Also of note are interesting trends regarding hiking preferences and gender, which are not explored in this dissertation but which bear further inquiry, particularly the fact that preferences surrounding internal aspects of hiking—motivation, frequency—are not differentiated by gender, while those involving external factors—hiking alone, hike duration—are.

A meaningful piece of data is the fact that a strong majority—greater than 95%—of individuals selected two or more devices. This may indicate that individuals are open to the inclusion of more compute-enabled gear in their hiking activities, which bodes well for ourselves and other researchers and designers wishing to create useful devices and systems to support hiking.

3.6.6 Contributions

Wobbrock and Kientz state that *Empirical* contributions such as those in this chapter are "evaluated mainly on the importance of their findings and on the soundness of their methods." Our methods are outlined earlier in this chapter. They are grounded in well-accepted methods and account for the limitations of Amazon Mechanical Turk as a data-gathering platform as described by [14, 15]. Internal consistenty in our results desribed above also suggest that our data gathering and analysis methods are sound.

Significant findings include: five hiking preference clusters, five technology preference clusters, correlations between hiking and technology preferences, demographic variations in preference, and the sheer number of individuals—95%—who prefer to carry a cell phone when hiking. These findings are significant because they ground HCI Outdoors in present realities and suggest new questions such as *what are individuals using smartphones for on the trail* and *what is the connection between hiking and technology preferences*. We outline our efforts to answer these and other questions in following chapters.

Chapter 4

Phase 1: Qualitative Short-Answer Survey

Continuing the *explantatory sequential* study design of Phase 1, we followed up our quantitative survey with qualitative inquiry, including a survey, interviews, and observations. In this study design, qualitative work explains results from initial quantitative work [61]. In the first phase, we learned what kinds of devices individuals prefer to carry when hiking and with what frequency, including demographic variations and variations correlated with stated hiking preferences. In Part 2, we seek to understand questions raised in Part 1 such as why individuals bring the devices they bring and how they use them. We also particularly sought to understand not only what individuals' hiking and technology preferences are, but what connections there are between hiking preferences and technology use preferences.

We began by administering an online survey which included open-ended questions. We opted for another survey to begin our qualitative inquiry in order to gather a deeper set of data to explain preferences and practices identified in the quantitative survey. In particular, we wished to understand individuals' reasons for bringing technology when hiking. Although they require more careful and thorough analysis, short-response surveys are a useful qualitative tool because open-ended questions allow respondents complete freedom in answering, leading to more detailed responses [58]. Such qualitative work also often leads to uncovering unanticipated ideas in individuals' answers [61].

We performed thematic analysis of 247 participant responses, arriving at a model describing individuals' technology preferences. In this model, individuals leave the *Civilized* world at home in order to go hiking in the *Natural* world, and use technology in various ways to *Bridge, Maintain,* or *Ignore* the boundary between these two worlds.

The contribution of this chapter is a theoretical model. In HCI, this kind of contribution is evaluated on novelty and soundness as well as on predictive, descriptive and explanatory power [86].

4.1 Methods

Our qualitative survey was conducted in July 2017. The content of the survey was identical to that of the earlier quantitative survey, including both hiking and technology sections. This allowed for clustering of participants as before in order to see if clusters and relative cluster sizes were in agreement. If individuals indicated a preference to bring a cell phone, headphones, separate GPS device, or tablet, they were asked to provide a three-sentence answer explaining why they bring this item when hiking. For headphones and cell phone, individuals were also asked to indicate why they *did not* prefer to hike with that item. We did not ask why participants brought less common or obvious single-use devices such as e-readers or action cameras.

Our study design followed the same process outlined for the previous quantitative study in Chapter 3 and was approved by the Brigham Young University IRB. Participants were again recruited via Amazon Mechanical Turk and the survey was administered using Qualtrics. The Qualtrics platform provided mechanisms to require responses of a certain length for open-ended questions. Survey participants gave implied informed consent before completing the survey and were compensated $0.75. The survey was designed to take 10 minutes to complete, and respondents averaged 6 minutes 58 seconds. Participants ranged in age from 18 to 73 (mean 34.33, median 32, sd. 9.90). A total of 247 responses were gathered from 239 unique U.S. ZIP codes, with 138 male and 109 female participants. Non-hikers were again included due to our desire in this early phase to gather as broad a set of data as possible.

4.2 Data Analysis

We adopted a thematic analysis approach based on the constant comparative method as initially proposed by Glaser and Strauss [28], and as described in Merriam and Tisdell [61] and Warren and Karner [83]. This is an inductive analysis method in which researchers immerse themselves in qualitative data, reading through it several times and then beginning a coding process. The goal of such inductive processes is to derive meaning and understanding from the data itself in a ground-up fashion, rather than apply meaning deductively to the data from the top down.

This coding process is characterized by finding meaningful recurring ideas in the data, creating codes that either directly use quotes from data (*in vivo* coding) or descriptive language (descriptive coding) to characterize these ideas. Through an iterative process, codes are identified and applied to pieces of data until a thorough and complete set of codes is arrived at. Codes should account for as much of the data as possible. They should also be carefully winnowed to find those that are the most meaningful and descriptive of the underlying data and ideas. Throughout this process, codes and data are compared to one other and to results from previous passes in order to refine and clarify results, hence the name *constant comparative*. It is also important to note here that individual codes can be applied as many times as appropriate, and that multiple codes can be applied to the same piece of data. [58, 61]

Our analysis followed the process outlined above, opting to use descriptive rather than in vivo codes. Through a careful iterative application of this process, we arrived at a clear and useful set of codes which described the data.

We then performed axial coding in order to determine broader themes which grouped these codes together. Axial coding is a step within the constant comparative method and coding process in which codes are examined and compared to one another, revealing patterns and connections. The ultimate goal of axial coding is to find a concise set of themes into which codes fit. Several different schemes were considered until we arrived at a scheme which fit the underlying data and codes. During axial coding, further refinement of descriptive codes also took place.

Upon arriving at a set of themes, we then explored several higher-level and more abstract concepts which might unify these themes. Ultimately, our abstract thinking led to the derivation of the overall model of "two worlds separated by a boundary," with further axial themes—higher-level themes which group our other themes. We will further unpack and discuss this model, its axial themes, and their themes in the remainder of this chapter.

Finally, we deductively applied our codebook to the data. Deductive coding is a top-down application of an existing set of codes and themes to data, and is also a means of testing one's codes and themes to see if they actually fit the data [61]. Two researchers coded the data independently, then met to resolve coding differences. In resolving differences, it was found that out of 2003 total applications between two coders, there were 198 instances where one researcher obviously missed a code application, requiring no discussion to resolve the discrepancy. There were 145 instances in which we discussed what code best applied before reaching an agreement. The primary result of these discussions was refinement of codes and their distinctive meanings and agreement about which codes to apply to participants' responses.

4.3 Results

The primary result of the open-ended survey was the development of a model which describes decisions made by individuals regarding technology use when hiking. In this model, which is discussed in further detail below, individuals hike in the Natural world and live in the Civilized world, and make technology decisions when hiking which largely fall into the axial themes of Bridging, Maintaining, and Ignoring the boundary between the two worlds.

We note that in results throughout this work, survey participants will be referred to as *PXX*.

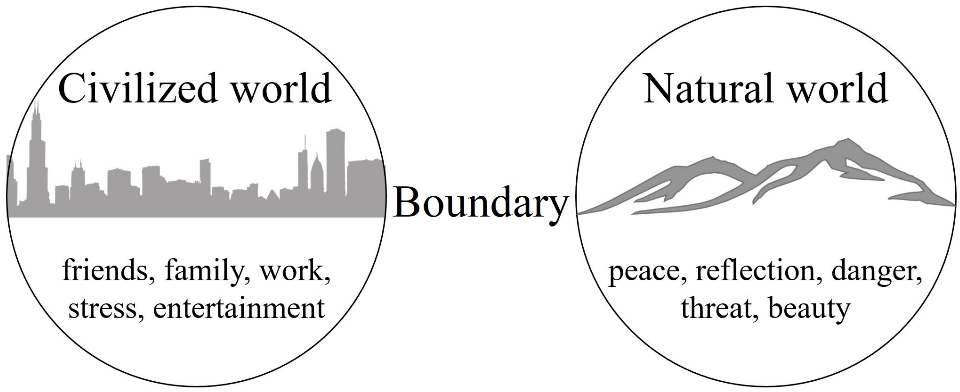


Figure 4.1: A diagram of our *Two Worlds* model.

4.3.1 Technology and the Boundary Between Worlds

Our model describes individuals using technology in relation to the boundary between the Natural world, where an individual goes to hike, and the modern, or Civilized world. Respondents expressed both positive and negative aspects of each world, and mentioned using a mobile phone in numerous roles with regards to the boundary between worlds. Figure 4.1 is a visual representation of each world and some of the characteristics associated with them.

The Natural World

The "natural" world is the world on the trail. As referenced in participant responses, the Natural world typically includes a wilderness element or an element of being away. One participant expresses this notion:

> Hiking is my chance to get away from the world. I don't want the world to be in contact with me. I want to enjoy nature not look at my screen. –P76

P18 and P32 express the idea that the Natural world includes beauty and tranquility:

> I don't want to be bothered by calls when hiking. I want to enjoy the peacefulness of the natural environment. –P18

> I like to take photos of the beautiful scenery and sometimes I post them (if there is reception). –P32

P137 expresses other notions with regards to the Natural world (emphasis added):

> I prefer to bring a cell phone when hiking for *safety and entertainment*. I bring my cell phone for safety because if I get lost or someone gets hurt and I need to get emergency help or contact someone. I also bring my phone so I can listen to music, keep track of my time, and steps and health fitness. I also bring it to use my headphone so I can listen to music or movies with down time. –P137

This quote highlights less positive aspects such as risk, threats, and even potential boredom in the Natural world.

The Civilized World

The Civilized world represents mundane elements of everyday life. Work, stress, and pressure appear in the Civilized world, as present in this response:

> I need to be ready to respond to emergencies that might come up, even if hiking is a way to 'get away from it all'. I typically don't use my phone on most hikes, it's just there just in case. –P200

"Getting away from it all" is a common English language colloquialism that means to go on vacation[1]. The "it all" from which P200 and others typically wish to get away is the routine elements and stress of daily life, as discussed in Chapter 1. However, the Civilized world also includes positive elements such as family and friends, safety, and comfort, things which this participant wishes to remain connected to:

> It also helps me stay connected with my loved ones, such as friends and family to let them know that I'm okay and they wouldn't have to worry about anything happening to me. –P51

[1]https://www.merriam-webster.com/dictionary/get%20away%20from%20it%20all

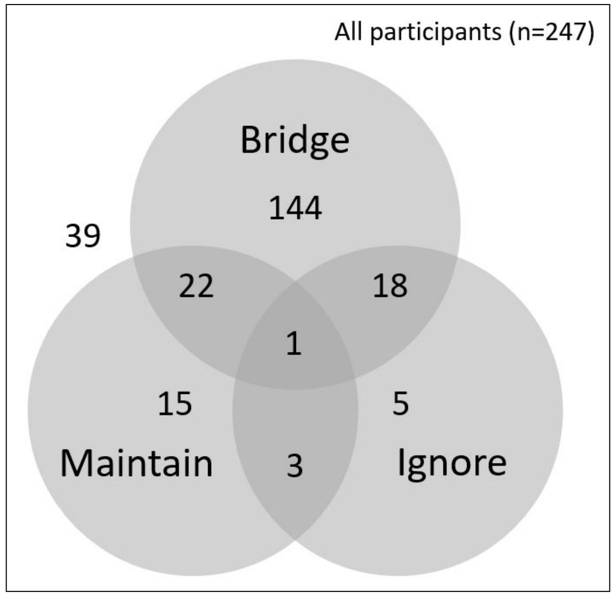


Figure 4.2: A Venn diagram showing how many responses contained codes from each of the three axial themes. Many responses contained elements of more than one.

The Boundary

The boundary between these worlds represents the physical and conceptual differentiation of one from the other. Generally speaking, participants seemed to explicitly or implicitly perceive this boundary, and decisions were made with respect to the boundary even if it wasn't explicitly mentioned. In quotes from participants, we often see each world as distinct from the other.

> Because if I need to do something while I'm there [hiking] I have it. –P185

P185 expresses the notion of being apart from the Civilized world and bringing a phone along because of that separation, or boundary. P198 similarly says:

> I essentially like to have some form of contact to the outside world, especially in case I ended up getting lost or some other emergency occurs. –P198

In both of these responses we see the notion of a separation between the world on the trail and the one back home. While participants who mentioned "worlds" typically referred to the Civilized world as the “outside world” (as P198 above), we opted to use the term “Civilized world” to avoid ambiguity between “natural” and “outside.”

Decisions regarding technology adoption and adaptation for hiking can be placed within the model, which may give insight into individuals’ intentions and desires regarding technology use, more specifically cell phones, when hiking.

We note here that the boundary between these worlds is not necessarily clearly demarcated. This is true in the physical as well as the conceptual sense. Although the boundary could be considered fuzzy and prone to shifts from time to time, participant responses clearly point toward a separation between worlds and technology’s place in bridging that.

4.3.2 Bridging, Maintaining, Ignoring

Attitudes, behaviors, and intentions expressed by participants with regards to the boundary fit into three axial themes: Maintaining the Boundary, Bridging the Boundary, and Ignoring the Boundary. We discuss each axial theme and the themes they encompass, and give counts of the numbers of excerpts coded with codes falling into each axial theme and theme. Table 4.1 gives counts for responses coded with each theme, grouped by axial themes.

It is important to note here that our *Two Worlds* model is not a categorization. The model does not cleanly partition individuals, rather responses were frequently coded with codes fitting into multiple axial themes. Figure 4.2 shows a Venn diagram which depicts the axial themes into which individual responses were coded. 43 responses were labeled with codes from 2 axial themes and 1 response was labeled with codes from all 3 axial themes.

Bridging Usage Types

The responses which fit into the themes in Bridging the Boundary can be slotted into two general types of usage: Communication and Data Transport. Communication usage involves uses such as calling or texting, while Data Transport involves uses such as listening to

Bridge		185
	Enhancing Natural World	117
	Bring Natural World Back	88
	Staying Connected	75
	Civilized World Concerns	21
Maintain		41
	Keep the Worlds Separate	24
	Block the Natural World	17
Ignore		27

Table 4.1: Number of responses in each axial theme and its related theme across all responses (n=247). Note that some responses fall into multiple axial themes and multiple codes—and hence themes—were applied to many responses.

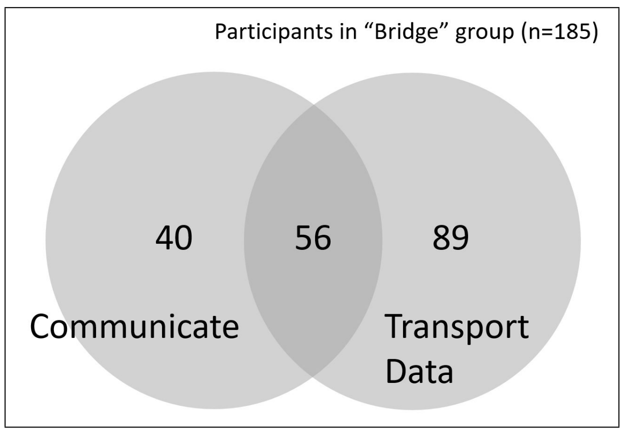


Figure 4.3: Purposes for bridging. Communication includes various forms of reaching people and data transport includes forms of transporting information across the boundary.

music or podcasts, or taking pictures or video. Figure 4.3 depicts the number of individuals whose responses fell into each usage type, as well as those that included both. Although 96 participants indicated that they use their phone for communication or both purposes, nearly as many—89—simply bring it along as a means to carry data to or from the Natural world, with no mention of communication.

Bridging the Boundary

185 Responses

The Bridging the Boundary axial theme encompasses staying connected to the Civilized world in different ways and for different reasons, as well as using technology to bring portions of each world into the other. This is the most common set of themes and codes applied to responses, which is not surprising given that even a modern smartphone is still primarily a communication device. This axial theme encompasses four themes as follows.

Staying Connected

75 Responses

Participants whose responses were coded into this theme indicated a desire to remain connected with the Civilized world while out in the Natural world:

> I also like to stay connected to the rest of the world even when hiking, and I can keep track of time with my phone. –P104

Statements in this theme included general notions of staying connected, as above, as well as the idea of being reachable to others still in the Civilized world:

> I also bring it for the obvious reasons such as not missing calls or texts. –P224

One participant expresses a desire to not only stay in touch but to make plans with people in the Civilized world while on the trail:

> I also bring it to view my emails and phone calls. I also text my friends to make plans for the rest of the day. –P243

Civilized World Concerns

21 Responses

Some responses indicated more than simply a desire to remain generally connected with the Civilized world. These responses were characterized by more substantive or compelling concerns within the Civilized world. Participants indicated need to stay abreast of these Civilized world concerns while in the Natural world. Some expressed the idea of keeping connected to loved ones:

> I also like to keep in contact with my kids if they need me. –P164

Others had occupational concerns they felt could not be abandoned while hiking:

> I am a realtor and need to keep current on client needs. If I am not available by phone a client may chose [sic] to use another person to show a house and I would lose a commission. –P140

> I run and [sic] online business and having my smartphone on me at all times helps me to sty [sic] on top of everything. –P214

This participant apparently did not wish to leave the Civilized world behind entirely:

> So that I can have access to news and information. Just because I am in the woods doesn't mean that the world stops operating. –P167

Enhancing the Natural World

117 Responses

This theme includes codes describing responses in which some portion of the Civilized world was brought along in order to enhance the hiking experience. Most commonly, individuals desired to bring and listen to music in order to enhance the experience:

> So I can listen to music and escape in my own world of sound. There's nothing like listening to your favorite playlist of great positive songs while you're hiking in the woods or mountains. –P10

While the most common use here is listening to music, mapping/GPS use is also common, and there is a strong sense in many responses of the phone acting as a sort of digital multitool:

> It has all of the tools I need. It can play music, work as a GPS, take pictures, contact people and make emergency calls. I don't really need more than that. –P7

This participant echoes the sentiment and mentions habitually carrying a phone, which we will discuss more later:

> It has most of those other devices all rolled into one. I can call for safety, listen to music, take pictures, track my steps, find my location, etc. Plus I generally just always keep it with me. –P173

These types of uses treat the phone as a digital backpack or multitool, in which data is carried across the boundary or the multi-functionality of the smartphone is leveraged for outdoor usage. Less commonly mentioned uses included checking time, flashlight, step tracking, geocaching, and others.

Bringing Part of the Natural World Back

88 Responses

In addition to bringing some portion of the Civilized world along on the hike, participants indicated a desire to bring or send back a portion of the Natural world into the Civilized world. Some desired to record photos or video:

> I bring a cell phone for hiking in order to take photos. I do a lot of hiking in national parks, so I like to be able to capture the moment. –P143

Blogging was also mentioned, as with this participant who wished to share their experience with others:

> I want to [sic] able to express myself when I go hiking so I can share my experience with people who couldn't give any time of day to my ego. –P106

These participants expressed an interesting aspect of this theme:

> I like being able to contact friends. Being in a different space can make the interaction different too. –P84

> I also use it to stream music if I stop to sit and write for a while, or sometimes to communicate with someone close to me if I've gone to clear my head. –P54

In these responses, the phone serves as a communication medium in which inspiration, peace, or clarity from time spent in the Natural world is shared with or inspires interactions with loved ones back in the Civilized world.

Maintaining the Boundary

41 Responses

The Maintaining the Boundary axial theme involves non-use or mitigation of usage in order to avoid distraction and seek an experience which is more closely attuned to the Natural world. Maintaining the Boundary also involves intentions in which the motivation is quite the opposite. In this behavior, the hiker uses the phone to block the Natural world by immersing themselves as much as possible in Civilized world experiences while on the trail.

Separating the Worlds

24 Responses

Of the 24 responses with codes belonging to this theme, 15 participants elected not to bring a cell phone when hiking. These participants indicated a desire to disconnect from the Civilized world so as to better enjoy their experiences in the Natural world:

> I want to feel like I am disconnected from electronics for the most part when I am hiking. I want to enjoy nature while I am walking, not be plugged in and worried about pictures or social media. –P23

> I do not want to be bothered with it. I also find it very intrusive with what I am doing. I do not want to be bothered by the outside world. –P37

In P37's response, we see again the notion of worlds that are separate from each other, with the Civilized world being referred to as the "outside world."

Nine participants preferred the safety or other features provided by a cell phone, but sought to minimize the impact it might have on their experience:

> In case I'm sick or injured, I can call someone. I don't use if [sic] for any other purpose. It is a safety matter. –P79

Blocking the Natural World

17 Responses

These participants indicated nearly the opposite intent from the previous theme: they desired to block out some portion of the Natural world with a part the Civilized world. In this theme, the Natural world experience is seemingly supplanted by Civilized world stimuli which occupy the senses, making it impossible for the individual to attend to stimuli from the Natural world.

We characterize this as blocking the Natural world because one seemingly cannot pay attention to or engage with the Natural world when engaged in something like games, movies, or browsing the internet, and that the reason one would engage in these behaviors during downtime in a hike is because one is at least partially disinterested in the Natural world as compared to the Civilized. This was often accomplished by some form of entertainment during downtime:

> When I take a break I can play games on it as well. –P70

> I can also use it if I take a short break to browse the internet and the like. –P60

> I like to have something to do while resting. On my tablet, I can read a book or play a game. –P239

> I want to be able to stop and take a rest and play on my iPad for a bit. –P194

Aggressively blocking out the Natural world includes listening to music when "sick of nature":

> so i can listen to quiet music and meditate softly if I get sick of the nature. Also if I get sick of talking to other people and need to relax. –P11

And easing feelings of boredom:

> I like to listen to music. I think hiking's boring, so having music while doing it eases the boredom. –P102

Others seek a more complete suppression of the Natural world, as P128 said "They [headphones] are mainly good for when I want to drown out the world." For some this may be due to discomfort with—as opposed to enmity or ambivalence toward—certain aspects of the Natural world:

> It has music on it. I like to listen to my music when I am hiking, because it calms me down. Sometimes I get afraid of mountain lions. –P193

Ignoring the Boundary

27 Responses

The Ignoring the Boundary axial theme includes elements of failing to see a boundary between the Natural and Civilized worlds. Responses coded into this theme include some element of bringing a phone out of habit, never leaving home without it or feeling naked without it. The first sentence of P29's response illustrates this:

> I like to have it [a cell phone] with me because I feel naked without it. Also, I can use it to snap quick pictures of things I see. I might also use it [sic] navigate or make phone calls if there is service. –P29

For this participant, taking a cell phone is like wearing clothing when hiking: it's just part of what she has with her when she leaves the house.

P32 posed an interesting alternative question which also illustrates ignoring the boundary:

> I always have a cell phone on me. I like knowing I can get in touch with someone. It would be better to ask 'Why WOULDN'T you have a cell phone while hiking?' –P32

P49's response includes elements of both ignoring the boundary and maintaining the boundary:

> In case of emergency, like if myself or one of my hiking teammates got lost. Plus its always in my pocket. I would feel naked without my cell phone. In general, I don't use it while hiking. It's just there for emergencies. –P49

P49 ignores the boundary in the sense that his phone is "always in [his] pocket" but maintains the boundary in that he does not "use it while hiking." Participant 49's response also includes the concept of feeling "naked" without a cell phone.

While this axial theme is the smallest, it is interesting because it suggests that for some people a cell phone is a normal part of life, even in the Natural world. In this axial theme, we do not see a principled struggle over whether or not to bring this artifact of the Civilized world into the Natural world. Similarly, most people do not struggle with whether or not wear shoes when they go hiking. They simply wear shoes, or bring a cell phone, because that's what they always do when they leave the house.

4.3.3 Other Axial Themes

Besides axial themes relating to the boundary between worlds, we found two other axial themes within our data: *Safety* and *Technical Considerations*. We did not include these in the *Two Worlds* model because the model focuses more on *experiential* aspects of hiking, while these themes revolve around more *logistical* considerations.

Safety/Emergency

201 Responses

The most common axial theme across all responses was safety considerations. 81.4% of individuals (201) in the survey mentioned safety in their responses, and 57.1% (141) mentioned it first. Many participants considered a cell phone an important safety device when hiking:

> I bring a cell phone in case of emergencies. It would be devastating to not have a phone if I got injured and were not around anyone...I also like having it in case another family member who isn't with me needs something or is going through an emergency. –P58

Responses in this axial theme fell into the themes outlined below.

On-Trail Emergencies

The most common consideration regarding the use of phones on-trail for safety purposes was to be prepared for emergency situations that might come up on the trail. Often this was mentioned in a general sense:

> It would be useful in an emergency. –P25

> In case of an emergency. –P72

> I LIKE IT FOR SAFETY IN CASE OF EMERGENCY. –P156

And alongside other uses:

> Mostly for safety reasons and for navigation/GPS. –P66

> I like bringing my phone in case of an emergency and sometimes to use as a camera if I don't feel like bringing my DSLR. –P158

Participants also mentioned specific concerns such as injury to self:

> Also, If I get hurt or am in an emergency situation I can call someone for help. –P168

Others were also concerned with the ability to help others who might be injured:

> I prefer to bring a cell phone just in case I get lost. Also, if someone gets injured you would need to call someone. I generally don't go far enough to require much more than that. –P40

Although we did not include the *Safety* axial theme in the *Two Worlds* model, we see ties here to *Bridging the Boundary*, as the phone is seen as a lifeline of sorts which increases the safety of the hiking experience.

Emergencies at Home

Apart from the potential for emergencies taking place on the trail, some participants also expressed a desire to be in touch in case of emergencies back home. P58's response above is an example of this theme. P86 expresses this idea:

> I like to bring a cell phone in case of emergencies. It is uncommon, but I would regret not being available in the event that something happened to a loved one. –P86

This theme is somewhat tied to *Bridging the Boundary* as well, as "emergency back home" could be considered part of the *Civilized World Concerns* theme. However, we placed it as part of the Safety/Emergency axial theme due to the particular concern for emergencies.

Emergency Mapping/Navigation

Getting lost was a fairly common concern, showing up in 47 responses, and the cell phone was seen as an effective means to avoid getting lost. Some participants considered this in the sense of dealing with being lost after the fact:

> in case of emergency and it has a camera. it serves several purposes. it also has a gps in case i get lost. –P24

> I bring this for GPS function in case we get lost as well as to be able to contact someone if there is an emergency –P44

While others seemed to consider it a means of preparing beforehand to avoid being lost at all:

> Also, if needed I can use GPS so I don't get lost. It's a safe guard for me. –P148

Participants often seemed to implicitly trust in the ability of their phone to help them in a dangerous situation, however some did mention the possibility of lacking coverage:

> A cell phone is just an essential piece of technology. In places with coverage it allows you to call for help if necessary. It can also be used as a GPS if that functionality is available, preventing you from getting lost while hiking. –P102

> Assuming there is cell coverage in the area, it is nice to have a way to communicate in case of an emergency. –P219

In this regard, the *Safety* and *Technical Considerations* axial themes overlap. Individuals who mentioned coverage or a lack thereof also all mentioned safety in their responses.

Technical Concerns

52 Responses

Some participants were careful to point out that they may or may not always encounter coverage while on the trail. Participants also made mention of various other technical considerations which the outdoors bring about.

Coverage Considerations

A relatively small number of participants ($n = 42$) mentioned coverage and whether they would have it or not while on the trail:

> It's my main way of communicating with the outside world. If I don't go too far from the city I can usually get a signal. I just feel safer when I know I can call for help when I need it. –P172

This participant realizes they may not have coverage but has experienced unexpected patches of coverage while hiking:

> I also tend to want to be able to call someone in an emergency. This is questionable on some hikes, but I have gotten cell reception in some surprising locations. –P239

These participants illustrate a pragmatic approach to carrying a phone when hiking:

> In case of an emergency, I can call for assistance, provided there is coverage. You never know if something happens to you or your friend. –P181

> Even if there is a chance that I will have trouble finding reception, I think it is important to have some means of communication on my person when hiking. –P136

Unrealistic Expectations

In contrast, some participants appeared to have an incorrect mental model of the level of coverage available or of other technical realities when in the outdoors. This was often manifest as a lack of consideration:

> I prefer to bring a cell phone for safety. If anything happens I can easily call someone. It's to protect myself. –P5

While we may guess that perhaps P5 only hikes in places with coverage, no indication of such is made here, and they appear to think it will always be easy to get help. Others expressed the notion that GPS chips in phones were always locatable:

> Worse case scenario, it has a gps locator in it, so if I am gone for to long I can be tracked down. –P53

> Also in case of emergencies, I might be able to call for help, and people will be able to find my last location. –P69

This participant, who did not indicate carrying a satellite phone, expressed a notion that their phone might somehow be able to connect to a satellite for coverage:

> Bringing my cell phone enables me to stay safe while hiking. In case of injury or if I get lost I must have my cell phone. Hopefully there is a satellite connection where I'm hiking. –P144

Others, cognizant of the limitations of coverage in the outdoors, planned accordingly:

> Also, it's nice just for knowing that if there was some sort of emergency, you could make a call for help. We don't go hiking so far out that we're ever without service. –P36

General Technical Considerations

Other technical considerations mentioned by participants included battery life:

> I can keep track of the time and if anyone calls ill be ready to answer. I also like to carry my phone just in case one of my other electronics dies. It is a reliable source in the time of need. –P42

> I also keep my cell phone on battery saving mode so I can use in case of an emergency to call for help. –P75

And offline map usage:

> Even without cell reception, I can use it as a camera and in an emergency it has a built in GPS to use with offline maps to help if we get lost. –P182

> I use it for emergency contact as well as a GPS. I download the Maps so they can be accessible offline –P192

As mentioned earlier, *Safety* and *Technical Considerations* are quite intertwined in participant responses. This participant's response is particularly compelling, and may have connections to some of the differences we noted in preference based on gender in our quantitative study:

> I prefer to bring a cell phone that I keep off so as to preserve battery, in case of emergency. I definitely consider safety in regards to bringing a cell phone with me. Something in my past mostly happened to influence this - I went on a hike in a national park across from my home once where I didn't bring my cell phone. During this hike, I was stalked by a very creepy man. –P97

Safety is a critically important aspect of hiking. Although our research at present has focused on other aspects of the hiking experience, there is certainly a great deal of work that can be done in support of hikers' safety and comfort.

4.4 Discussion

Our open-ended survey yielded short-answer responses from 247 respondents. Inductive thematic analysis of responses following an open coding approach and using the constant comparative method yielded several interesting themes, culminating in the development of a *Two Worlds* model in which hiking takes place in the Natural world, which is distinct and separate from the Civlized world in which we live, and technology choices reflect attitudes regarding Bridging, Maintaining, or Ignoring the boundary between these worlds.

4.4.1 Relationship to Other Models

After developing the *Two Worlds* model, we noted that its connection to Kaplan and Kaplan's [43] four properties of restorative environments. Time spent in a restorative environment restores one's ability to maintain directed attention. Directed attention draws upon William James' notion of voluntary attention which requires effort to maintain [35]. In the Kaplans' theory, nature provides an ideal restorative environment for rebuilding directed attention, a critical cognitive resource. Restorative environments have four characteristics: (1) being away: a departure from the routines of everyday life, (2) extent: a sense that the environment continues beyond the currently perceived reality in predictable ways, (3) fascination: the ability to hold one's attention without effort and (4) compatibility: activities supported are compatible with one's purposes for being there.

Our model involving the Natural and Civilized worlds seems consistent with aspects of the work of the Kaplans in the following ways:

Being Away: the *Two Worlds* model embraces a boundary between worlds and a sense of being away from aspects of the Civilized world that are "ordinarily present" ([43], p.183) at home or work. The Natural world represents an escape from work, distraction, and certain kinds of mental effort—all of which are part of Kaplan's property of "being away." Participant responses seemed to indicate a separation between the world on the trail and the world back home, as exemplified by P198: "I essentially like to have some form of contact to the *outside world...*" [emphasis added].

Extent: Kaplan describes extent as "the sense of being in a whole other world." ([43], p.148). Our model echoes this sense of "being in a whole other world." Separate worlds appeared directly in some participant responses, as P198 above. This notion of *separate worlds* guides the framing of our model and seems consistent with the notion of restorative environments having extent.

Compatibility: Kaplan says of this requirement: "the setting must fit what one is trying to do and what one would like to do." [44] Hikers choose to go to the Natural world in order to escape the daily pressures of the Civilized world, and find an environment that fits their purpose and goals in doing so. Our results also show that hikers adopt and adapt technology in order to make their environment and/or experience on the trail more compatible with their purposes in hiking. For instance:

> I prefer not to bring headphones because then I can't listen to the nature around me. Part of the reason to hike is to enjoy the sights, sounds, and smells around you. With headphones, you can't enjoy all of those things together. –P25

P25 chooses not to bring headphones because he finds nature most compatible with his purposes when he can hear sounds and see sights. By way of contrast, P26 finds that music enhances the experience:

> Yes, to listen to my favorite music and meditate. I like to look at the beauty of nature and get inspired. –P26

4.4.2 Conclusion

Analysis of data from our short-answer survey led to the development of a model describing individuals' approach to adopting and adapting technology for use in hiking. In this model, termed the *Two Worlds* model, individuals use technology in relation to the Natural world where they are hiking, the Civilized world where they live and perform daily tasks, and either Bridge, Maintain, or Ignore the boundary between these worlds with their technology decisions. We anticipate that this model will prove valuable designing technology for hiking and other outdoor activities. The *Two Worlds* model also leads to interesting considerations and questions that can be applied during the design process. Further work detailed in later chapters validates and builds on this model.

4.4.3 Contribution

In this part of Phase 1 we developed, through thematic analysis of short-answer survey responses, the *Two Worlds* model., in which individuals make use of technology in bridging, maintaining, or ignoring the boundary between the Natural and Civilized worlds, often participating in behavior and exhibiting preferences that fall into two or all three of these axial themes. This model describes and explains technology decisions made by individuals when hiking.

Theoretical contributions in HCI, such as this model, are "evaluated based on their novelty, soundness, and power to describe, predict, and explain." [86]. The model is novel because it is the first model that describes why people bring and use interactive computing while hiking. Similar models have broadly described advanced amateur runners' specific needs [49], and explored the more narrow experience of using GPS and heart-rate monitoring devices for running and orienteering among elite and amateur athletes [77]. Our model explores a context which is different from these in its location, pace, fundamental goals and approaches, and participants.

The soundness of our model rests largely on the soundness of our approach. The methods employed in our survey design, implementation, and deployment were based on the same well-accepted methods described in the previous chapter. Further, we applied well accepted thematic analysis methods described in [58] and [61]. Lastly, the resulting model can be connected to existing models of time in nature such as Kaplan and Kaplan and Ulrich [43, 80], which strengthens the external validity of our results.

Additional qualitative work described in the next two chapters validated and led to the expansion of the *Two Worlds* model, testing and increasing its prescriptive and predictive power.

Chapter 5

Phase 1: Interviews and Observations

Our short-answer survey and its results from the previous chapter continued the *explanatory sequential* study design by beginning to explain and lend depth to results from our quantitative work. In our short-answer survey, we collected 247 responses from individuals regarding their hiking and technology preferences. Thematic analysis of this data served to deepen our understanding of preferences and practices, and led to a new understanding of individuals' reasons for bringing technology when hiking. This culminated in the development of a *Two Worlds* model describing these decisions, as described in the previous chapter.

In this chapter, we continue the *explanatory sequential* study design with interviews and observations. Employing other methods allowed us to augment and validate results from our qualitative survey. Surveys are limited as a qualitative instrument in that they do not allow for follow-up on interesting ideas. As such, they can only probe so far into understanding an individual's experience. Surveys are also prone to recall bias, which is when study participants tend to over- or under-represent their preferences or practices as compared to reality.

Interviews allowed for in-depth exploration of themes encountered in our short-answer survey. Observations led to better understanding of practices. They also acted as a means of verification regarding individuals' recollection about their on-trail practices.

Conducting multiple data gathering steps increases validity by triangulating results. In qualitative and mixed-methods research, triangulation is an approach wherein multiple instruments are employed in multiple data-gathering steps, with each exploring the same research question or questions [58]. Such an approach can lead to a more thorough, accurate, and in-depth understanding of the phenomenon in question. Within the scope of our work, interviews and observations expand, clarify, and/or correct errors in results from the short-answer survey. This ultimately led to the validation and broadening of our *Two Worlds* model.

This chapter rounds out the *Theoretical* contribution of the *Two Worlds* model outlined in Chapter 4 [86]. In particular, the work outlined here establishes the *descriptive* and *explanatory* power of the model, demonstrated through its application to data gathered through interviews and observations. Further, the uncovering of a new theme, *Curation*, and its eventual inclusion as an axial theme within the *Two Worlds* model led to a more fully developed version of the model. This addition bolsters the model's *descriptive* and *explanatory* power as well as its *soundness*. Deeper discussion of these changes follows later in this chapter.

5.1 Interviews

We conducted interviews with 16 hikers to better understand hiking and technology preferences. Interviews allow for gathering of more in-depth data about individuals' experience, thoughts, feelings, and preferences. Interviews benefit from the opportunity to ask follow-up questions in order to better understand and to explore new and interesting ideas that come up. As an interviewee thinks, responds to questions and follow-up questions, and talks at greater length about a given topic, they may begin to make connections and uncover ideas or insights which a survey could not elicit [58, p. 178].

5.1.1 Methods

Participants were recruited from personal hiking circles and social media hiking interest groups. We chose to sample people interested in hiking rather than the general populace as

ID	Age	Sex	Region	***Two Worlds*** **Themes**
IP1	25	M	West	Enhancing the Natural World, Ignoring the Boundary
IP2	26	M	West	Keeping the Worlds Separate, Enhancing the Natural World, Bringing the Natural World Back
IP3	66	F	West	Staying Connected, Enhancing the Natural World
IP4	40	M	West	Ignoring the Boundary, Bringing the Natural World Back
IP5	26	F	West	Enhancing the Natural World, Bringing the Natural World Back, Staying Connected
IP6	59	M	West	Enhancing the Natural World
IP7	34	M	West	Enhancing the Natural World, Bringing the Natural World Back, Staying Connected
IP8	34	M	Southeast	Bringing the Natural World Back, Ignoring the Boundary
IP9	39	F	West	Keeping the Worlds Separate, Enhancing the Natural World
IP10	35	F	Southeast	Keeping the Worlds Separate
IP11	42	M	West	Enhancing the Natural World, Staying Connected
IP12	53	F	West	Keeping the Worlds Separate, Enhancing the Natural World, Bringing the Natural World Back
IP13	50	M	West	Enhancing the Natural World, Bringing the Natural World Back
IP14	18	F	West	Keeping the Worlds Separate, Enhancing the Natural World
IP15	19	F	West	Keeping the Worlds Separate, Enhancing the Natural World, Blocking the Natural World, Bringing the Natural World Back, Staying Connected
IP16	24	M	West	Bringing the Natural World Back

Table 5.1: Interview study participants.

in our surveys because those who identify as hikers were more likely to have thought in depth about preferences and practices regarding the inclusion of computing in hiking.

We conducted 16 interviews, with each lasting between 15 and 30 minutes. 10 interviews were face-to-face and 6 were over video chat. Interview results were saturated in the sense that no significant themes appeared in only one interview. Of 16 interviewees, 7 were female and 9 were male. Ages ranged from 18 to 66 (mean 36.81, median 34.5, sd. 13.71). 14 interviewees lived in Utah while two lived on the East Coast of the United States.

In our χ^2 analysis of quantitative data, region was not shown to have statistically significant correlation with hiking or technology cluster. Hiking experience ranged from a few years to decades. Interview participants gave informed consent before the interview and were compensated \$15.00 for their time.

Interviewees were first asked to fill out the survey from Phase 1 in order to relate participant responses to survey responses. This also guided the direction of the interview by informing specific areas to explore. Interviews generally proceeded with a discussion of the participant's hiking and technology preferences, with the interviewer making note of interesting ideas to follow up on with regards to connections between hiking and technology preferences. Participants' survey responses guided questions about what technology is used on the trail, how, and for what reasons.

We recorded audio of each interview and used a transcription service[1] to convert the audio to written text. The first several interview transcripts were initially reviewed by two researchers in order to determine their accuracy. The accuracy of these first transcripts was found to be near perfect, after which we did not continue to review transcripts.

Interview data was analyzed inductively following the constant comparative method as outlined above in analyzing open-ended survey results. The main theme found in responses was *Curation*, which became a new axial theme as discussed below. Our *Two Worlds* model was also deductively applied to interview data, in order to test the model's validity and soundness [61, pp. 210-211] as well as to attempt to better understand interview data. These results are also described below. Analysis of this data and the *Curation* theme together with comparison with existing data and themes led to the expansion of the *Two Worlds* model to embrace new axial themes.

[1]https://www.rev.com/

5.1.2 Results

Inductive thematic analysis of interview results led to the discovery of a new axial theme: *Curation*, where individuals adopt and adapt technology to match their preferences and intents when hiking. Deductive application of our *Two Worlds* model also revealed that our axial themes of bridging, maintaining, and ignoring the boundary were a good fit for various approaches taken by individuals as discussed in interviews. Further, hikers vary widely from each other as well as individually in terms of how their approaches fit into the model and whether they bridge, maintain, or ignore the boundary, or (most common) some combination of all three.

Curation

Our previous research uncovered a broad array of preferences and practices relating to hiking and technology use when hiking. Our χ^2 analysis of quantitative results also suggested a connection between hiking preferences and preferences for technology use when hiking, confirming intuition. For example, those in the *Meditators* cluster were more likely to bring headphones.

Interview results confirmed that hikers selectively adopt and adapt technology for use when hiking. This process, which we term a process of *Curation*, is undertaken by hikers in an attempt to find and use systems, devices, and apps that support their goals and intents when hiking.

Preferences Drive Practices

One theme of *Curation* is hiking preferences driving preferences towards technology use when hiking. For instance, IP4 is busy as a stay-at-home dad to his son, who has a chronic illness which is at times severe. He indicated that he hikes frequently for both fitness and what he terms "therapeutic reasons." His approach to hiking is unique compared to others interviewed in that he describes his hikes in terms of their *duration* rather than their *distance*:

> And then on the weekend I try to get out and do anything from like an hour with my wife to sometimes I go two to four hours. –IP4

In order to make his hike fit into the specified time window, he needs to know the time, but he does not care for watches, so he uses his phone to tell time

> I take it [a smartphone] with me every time 'cause I, I don't like wearing a watch. So that's my only timepiece and that's almost its only function. –IP4

When prompted, he indicated that he always thinks of hikes in this way because he is fitting them into a typically busy schedule. He also reported that he likes to hike at a relatively high intensity. This hiking approach, among other preferences, informs his approach to technology use when hiking.

IP2, who typically hikes with his girlfriend, interview participant IP5, has a relatively strong aversion to technology in general, and in particular to his smartphone:

> I really hate my phone. I hate my, like the obligation to be in contact with everyone or to always be accessible. So it's very much a hate relationship, but I like what it does so I have to, I feel like I have to use it. –IP2

We see here that he is somewhat conflicted over his phone since it is a very useful tool in his day-to-day life, but he finds it and the responsibilities and expectations it represents burdensome. Interestingly, this conflict appears to play out in his technology use when hiking as well. He indicated using the phone for mapping and GPS location, however he also indicated his distaste with the experience of using it on the trail:

> Almost every time I use it, I'd say it's a distraction. [I] Kind of shame myself. Yeah. Like we were out hiking yesterday, we both had the morning off and I was checking my email while it's like, we were paused–it's like, what am I doing? –IP2

IP9 typically hikes with her family as a way to disconnect from daily life and technology:

> Um, for me I think it's you know spending that time together, that we can try to somewhat get away from all the technology and stuff at home. You know what I mean as far as the screen time? The kids want to be on video games. They want to be doing all that. So to me it's nice that they can leave that stuff behind and then we can just get out and be together, you know as a family, enjoying nature and just kind of, you know, making that time to create memories. IP9

She indicated that she does not bring her phone—a flip phone—when hiking, relying on her husband, participant IP11, who has a smartphone. Further, she indicated that her husband does not use his phone often except for to take pictures and sometimes to let their children know how far they have gone and how much farther they need to go.

She also said that they are careful to preserve their family hiking time by ensuring that their children do not bring technology when hiking:

> I mean, we may, if, with [son] being a little bit older, he may sneak his iPod just for music. Though like I said, we try to when we're out with them, we try to make them put that stuff away so it's like, this is family time. You can do your electronic or music stuff later when we're back in the car or something and everybody's tired and grumpy and needs their quiet space. –IP9

In each of these quotes we see preferences and intents for hiking—family time, getting away, not wearing a watch, exercise—driving practices—leaving most electronics behind, trying to minimize its use and impact on the hike, using the phone for timekeeping and mostly leaving it alone.

Curation is a Process

The other theme within *Curation* is that individuals appear to go through a process of adopting and testing different technologies in order to determine which suit their preferences and are usable. In the following quotes we see that IP11 has spent time and effort in seeking out and trying different apps for tracking his hiking and trail running, and that he has found some to be more or less compatible with his preferences and intents:

> Um, so I will use, like, Trail Reports, and All Trails, and Find Trails, too. The nice thing about All Trails is you can filter it. So you can, if you want go mountain biking, you can filter it for mountain biking. If you want a kid friendly trail, you can filter it for kid friendly trails. You can look and say, "Well, we're here. What trails in this vicinity." Or you can look and scroll and say, "Okay, well here's some easy trails up Little Cottonwood." –IP11

> ...I didn't like the Strava app, because the Strava app, unless you pay, won't tell you what pace you're currently running. It just tells you what your average is over your run. So, that's why I switched to Map My Run. But, like, uh I don't think, you know, there's sometimes you'll try a new app, and you're like, "Well, that app kind of stinks."...And the nice thing that Strava does is that, um, Map My Run doesn't do, is it'll track your time on certain, on, you know–if you run a certain segment, it'll tell you right? This is your third best time. –IP11

In contrast to IP11's use and enjoyment of the AllTrails app [2], IP2 indicated trying similar apps with a different outcome:

> Um, we've tried in the past to use the apps, but the apps are so complicated that we give up before we ever get it figured out. –IP2

IP6 indicated that he had used an activity tracker in the past, but stopped using it when he found that he was using it sparsely:

> Yeah, I just started with a smartwatch, so...and we've had a Fitbit, too. But it was mainly just, occasionally I would use it to say, okay, let's see, how many steps

[2]

> am I taking? Or- how- what's my blood pressure, or what's my heart rate at? [Interviewer: So you're not, like, daily wearing the Fitbit, or...?] No. But I do wear the smartwatch all the time. –IP6

We see in these quotes how individuals try different systems and apps, adopting some and abandoning others, in an ongoing process of finding those that best suit their preferences and intents.

Bridge, Maintain, Ignore

We also deductively applied our *Two Worlds* model to interview data, which helps to further understand interview data as well as to validate the model. Inductive data analysis, as performed with open-ended survey data and as previously detailed with regards to interview data, seeks to gather meaning "from the bottom up" by starting with small pieces of data which are compared and contrasted, building increasingly larger units of meaning. Deductive analysis works "from the top down," applying existing understanding to new data in order to help explain and understand it. This type of analysis can also act as a validation step for existing codes, themes, axial themes, and models.

In deductively applying our model to interview data, we found many instances of individuals bridging, maintaining, and ignoring the boundary between the Natural and the Civilized world.

Bridge

Interviewees indicated *Bridging the Boundary* in ways consistent with those mentioned by survey participants. Responses which fit into this axial theme and its related themes involved using technology to connect the two worlds in some way. These included behaviors such as keeping in touch and bringing portions of each world into the other. IP3 uses AllTrails to track and to allow her husband to track her hikes:

> I have an app called AllTrails, and I pull up that AllTrails app, right? And I use that on my phone to track. Um, also my husband can track my phone. Since I hike by myself all the time. That's real critical. –IP3

IP3 also bridges the boundary by using AllTrails for navigation:

> So, but I will say that, that AllTrails, or even just the satellite version of it, it will always show you trails if you're wandering and things. Um, I would be absolutely lost without it. –IP3

IP1 indicated that he both hikes and runs trails, and brings his phone most, but not all of the time. He indicated that he uses his phone for a number of things:

> For taking pictures, listening to music, uh, if I get lost, I'll use, use the map or something. But, mostly music. –IP1

Listening to music, the main use indicated by IP1, was classified in the *Enhancing the Natural World* theme.

IP10 reported an instance of the *Civilized World Concerns* theme. In this particular instance, she went hiking with a friend who owned a smartphone when she did not yet. About an hour into the hike, her friend attempted to check his email with his smartphone but was unable due to lack of service. When he realized this, he became very concerned because he was involved in a political campaign and it was a presidential election year in the United States, and he felt he had already been away too long given the circumstances. In this case, a failed attempt to bridge the boundary led to their hike being cut short.

Photography, the main component of the *Bringing Part of the Natural World Back* theme, was mentioned by all eleven interviewees. Several indicated interesting or unique uses for their camera:

- IP4 said that he sometimes took pictures to track the receding snowline, or to document interesting rooflines of nearby homes

- IP7 indicated that on family hikes he and his wife give a small camera to their children in order to keep them occupied during the hike
- IP8 is interested in birdwatching and uses an app [3] to track birds as well as a different app (not specified) in order to determine favorable lighting conditions for landscape photography
- IP10 told of a summer where she and her mother hiked the same trail every day and took pictures to document the different wildflowers as they bloomed

IP7's use in particular is an interesting case of adapting technology in order to suit a need–keeping children occupied on a family hike. IP8's use of a birdwatching app is another case of bridging, in this case *Enhancing the Natural World* by bringing along a guide from the Civilized world in support of his birdwatching hobby.

We note that the foregoing examples also demonstrate both the *Communication* and *Data Transport* usage types identified in the survey. Some bridging behaviors were about maintaining contact in from the Natural back to the civilized world or vice-versa, while others primarily involved bringing some aspect of one world into the other, such as photos or map data.

Maintain

Several interview participants indicated some level of preference for *Maintaining the Boundary*. This was particularly so in cases where hikers wanted to focus on connecting with others, as with IP5, who hikes most of the time with her boyfriend IP2:

> Cause, I think, like, when I'm hiking, I'm kinda trying to get away from it and kinda have that break where it's like, I'm disconnected from everything else, and I can just be, like, in nature, like, really present and just like, whether it's just myself or with Boyfriend, where it's just like, I don't have to deal with anything else. –IP5

[3] https://www.sibleyguides.com/about/the-sibley-eguide-to-birds-app/

IP1, who indicated that music was his primary use for the phone, but that he didn't listen all of the time, also indicated a desire at times to be fully present in the Natural world:

> Like, the tuning people out is kind of the nuisance of the headphones. Like, sometimes I won't wear headphones because I want to be aware of people. –IP1

These responses represent *Separating the Worlds*, to one extent or another. IP15 presents an interesting combination of responses. Her stated on-trail behavior seems consistent with *Blocking the Natural World*:

> Um, I take my phone. And maybe a Bluetooth speaker. –IP15

A Bluetooth speaker creates sound that would drown out sounds in the natural world, for this individual as well as for anybody near enough to hear. However, elsewhere the interview she states an attitude and ideas about hiking consistent with a *Separating the Worlds* approach:

> Um, I just, I honestly think that this earth is so beautiful, and like just being like in nature makes me feel like so at peace. And its you get away from like the like the busy part of life. And like it's really nice to just take a break, and like breath in like the fresh mountain air. So it's really peaceful. –IP15

Her stated reason for listening to music on the trail is because it "gets me going." This illustrates the crossover often present between the axial themes of the *Two Worlds* model: although it would seem there is tension between an approach that wishes to enjoy the peace of nature and one that would play music out loud on a bluetooth speaker, IP15 finds the music inspiring and motivational, contributing to her overall enjoyment of the experience–*Enhancing the Natural World.*

Ignore

Participants in interviews also made indication of preferences and behavior that were consistent with *Ignoring the Boundary.*

IP4's practice of carrying a phone and referring to it almost solely for telling time with sparse picture-taking is in line with maintaining the boundary and with bringing part of the natural world back. However, his preferences and practices appear more inline with *Ignoring the Boundary*. When asked about his typical use of technology apart from hiking, IP4 said:

> A lot, I'm home with a chronically sick kid so I use it half the day...I spend very little time, some time researching his meds and I mean other times just kind of keeping up with people being, while I'm isolated in the house, you know. So and I watch a lot of, might watch a lot of shows or keep the live stream of news programs. So I'm always actually, I'm using my phone all day for some kind of entertainment. –IP4

IP4 uses technology fairly heavily on a day-to-day basis, but very sparsely when on the trail hiking. This may be consistent with *Separating the Worlds*. However, when asked whether he put the phone in airplane mode in order to simply focus on it as a timepiece, he responded:

> Well no, although it's funny I was actually on Cascade Saddle [a local mountain ridge/saddle] and my phone rang, I was shocked. I just don't expect it to ring as its often out of service and my mom was calling, it was like, "Hey [IP4], what are you up to?". –IP4

This indicates that his approach is more in line with *Ignoring*–he simply goes hiking, bringing his phone and using it for the functions that fit his current activity—hiking—but without conscious decisions regarding its use or the crossing of a boundary between worlds. IP11 gives an explanation which characterizes *Ignoring the Boundary* quite well:

> So I would say that technology and the hiking is just kind of like everything else, right? Technology is how I do my [church responsibility], technology is how I, you know, parent my kids, because my kids' calendars are all on this **indicates

> phone**. I can text my kids, and uh, you know, I can look up their grades. And I can, uh, I can, it it, you know, and everything at church and everything at home, and just sort of the technology sort of just follows all of those things, and it's the same for hiking and trail running. –IP11

Overall, each participant in interviews displayed aspects of multiple axial themes of the *Two Worlds* model, which is consistent with previous findings that individuals' motivations, preferences, and practices are nuanced and variable. Refer to Table 5.1 for a list of themes relating to each participants' responses.

5.2 Observations

For our final qualitative data gathering activity, we conducted observations. In qualitative observation [61], one or more researchers visit a location or locations where a phenomenon of interest is taking place, specifically looking for and carefully observing specific behavior identified beforehand as relating to the phenomenon under study. Sparse notes are taken (allowing for more careful observation) and carefully filled in later with as much detail as possible. Observations are lacking in their ability to understand individuals' thoughts or motivations, but important as a method of validating and understanding actual behavior, as individuals' descriptions of their behavior may be less than factually accurate—either intentionally or accidentally—in other data gathering methods.

Our purpose was to observe instances of hikers using interactive computing devices during a hike, with a main purpose of determining whether observed behavior was consistent with behaviors indicated by survey respondents and interview participants. We also hoped to understand how on-trail behavior correlates with data gathered in other phases.

Trail	Difficulty	Traffic	Typical User	Cell Phone Coverage
Delicate Arch	Moderate	Heavy	Tourists from around the world	Sparse
Landscape Arch	Easy	Moderate	Tourists from around the world	Sparse
Bridal Veil Falls	Easy	Light	Locals, casual walkers, families, runners	Reliable signal
Y Mountain	Hard	Heavy	Locals, fitness enthusiasts, some tourists	Full coverage
Big and Little Cottonwood Loop	Easy, moderate and hard	Heavy to very light	Families, hikers, trail runners	Mostly covered
Timpanogos Saddle	Hard	Moderate to heavy	Hikers, trail runners	None on trail, coverage at saddle
Stewart Falls	Easy	Heavy	Local sightseers, families	Reliable signal

Table 5.2: Trails included in observation study.

5.2.1 Methods

Observation plans, as with all others, were approved by the Brigham Young University IRB. Observations were conducted on several trails in Utah, United States between May and August 2018. In total, we conducted 35 hours of observation between four observers.

Guided by behaviors mentioned by participants in quantitative and qualitative surveys, we created a list of behaviors to look for during observations. These included things such as looking at and interacting with a cell phone, picture taking (with a phone or separate camera), headphone use, and interactions with watches.

In previous data, technology use was connected to an individual's purpose for going hiking. To this end, we selected trails which we believed would be used by hikers with different purposes. This included tourists, local families out for a walk, fitness enthusiasts, and trail runners. We also selected trails with differing degrees of cell phone coverage, difficulty levels, and remoteness. The trails used for observations and their characteristics are shown in Table 5.2.

Observations were conducted while the observer traveled on the trail or with the observer seated inconspicuously near the trail. No personally identifying information was collected. We did not identify ourselves as researchers unless asked. This design allows for observation of authentic behavior with little or no impact on hikers' privacy. The people we observed did not give consent and were not compensated but were located on or within 2 meters of a public trail or trailhead with no reasonable expectation of privacy.

Brief notes were made during observation and then fleshed out within 6 hours after observation. Notes taken on the trail consisted of written notes and voice recordings. Observers met several times prior to, between, and after observation sessions to ensure agreement in observation and note-taking practices, and to compare notes after each observation session.

Observation notes were compiled into a single text collection for analysis. Data analysis was consistent with previous analysis methods as outlined, and included inductive analysis through examination of recorded behaviors, as well as notation of recurring behaviors, which were subsequently discussed in depth between researchers. In particular, analysis sought to determine whether behaviors matched results from survey and interviews. No new themes were revealed in inductive analysis.

Limitations

It is often difficult or impossible to determine exactly how an individual is using a smartphone. Some uses, however, are particularly obvious such as calling or taking pictures. Also, general patterns of behavior including the location, frequency, duration, and intensity of focus during phone interaction can be readily observed. Observing such patterns can give a reasonable amount of understanding of actual practice in conjunction with stated practices from other data.

Another limitation of observations is that we were not able to see everything that individuals were carrying with them. Because of this, we did not collect specific counts of devices observed, as such numbers would not be accurate reflections of what was actually carried or used. We did, however, note relative frequencies of observing different devices on each trail, as this gives an overall picture of individuals' usage intents with regards to hiking on a particular trail.

5.2.2 Results

Data gathered during observations and its subsequent analysis led mainly to a confirmation of previous results. Specifically, individuals appeared to carry and use the types of devices indicated in previous results, and with relative frequency in line with previous results as well. Interactions with devices matched behavior patterns reasonably consistent with those indicated in surveys and interviews. Individuals' apparent decisions in this regard also seemed to indicate a matching of devices and uses to intents as in a curation process, and we observed uses which were consistent with themes from the *Two Worlds* model.

An important point to note is that both observations and interviews help to illustrate the important difference between carrying a device and using a device. Although 95% of individuals in the quantitative survey indicated a preference for bringing a cell phone when hiking, most individuals we observed only interacted with cell phones sparsely, and largely at trailheads and observation points. This is in line with statements made by interviewees, such as IP1, who indicated that he uses his phone and headphones "maybe half the time," particularly leaving them behind when with others. IP11 indicated that his cell phone use occupies "maybe five minutes per hour of hiking."

Relative Frequency

We observed that smartphones were the most commonly seen piece of technology in use on trails, being used by individuals on every trail we visited. Headphones were not readily observed on most of the trails, however the majority of users on the Y Mountain trail appeared to be using them. Users on this trail were also more likely to be seen using what appeared to be separate GPS devices, largely watches that they interacted with at the trailhead, either when coming or going.

Separate cameras, including action cameras, were observed to be in relatively heavy use at the far end of the Delicate Arch trail (where the arch is located), as well as to a lesser extent on the Landscape Arch, Stewart Falls, and Bridal Veil Falls trails.

Behavior which was less frequently mentioned in the survey and interviews was also less frequently observed. For instance, a handful of individuals stopped at the top of the Y Mountain trail and spent time interacting with their phones in a manner consistent with scrolling through social media or reading, however such behavior was not readily observed elsewhere, and most hikers on this particular trail simply observed the view or turned around to head back down.

Also observed relatively infrequently were instances of hikers using the speaker on their phone and/or a Bluetooth speaker to listen to music played out loud. In one particular instance, an individual turned off the music he was listening to when reaching a seating area with benches at the top of the Y Mountain trail, but after a while at that location, turned it back on.

Curation

An interesting aspect of data from our observations is the agreement between individuals' apparent goals, their selected trail, and the technology they carried and used. We consider such observations as instances of *Curation*.

For instance, we observed many individuals wearing running or trail running shoes and workout clothing at the Y Mountain Trail. Many such individuals were either hiking solo or in relatively small groups, and quickly made their way from the parking lot onto the trail, pausing to consult a watch or insert earbuds before running up the trail or hiking at a relatively quick pace. Such behavior aligns with other aspects such as the steepness of the trail, its popularity as a place to go for a strenuous workout, and the time of day (early morning). This is also where we saw the most headphone users, consistent with those who mentioned using music as a motivator on the trail.

The Delicate Arch and Landscape Arch trails are well-known tourist destinations. On these trails, we observed technology use consistent with tourism. This included the highest number of individuals with separate cameras and the highest incidence of individuals taking pictures and video. This also fits with correlation between the *Camera* and *Tourists* technology and hiking clusters.

At the other trails, which are frequented by a wider range of individuals and for a wider range of purposes, we also observed a wider range of device use and non-use. All of these observations are consistent with adopting and adapting technology to fit one's needs and intents through a curation process as discussed below. They also contribute to the internal validity of the data and results gathered through our study.

Bridging the Boundary

Many instances of *Bridging the Boundary* were observed, including behaviors which fit into three of the four themes which make up this axial theme.

Staying Connected

Behaviors in line with *Staying Connected*—calling, texting, other communications—are somewhat more readily observed than other types of smartphone behavior. An individual holding a phone to their head and talking is clearly in a phone call. One who pulls out their phone, looks at it for a moment, makes thumb motions consistent with typing or swipe typing, and then returns the phone to a pocket or stops looking at it, only to do the same again shortly, would appear to be texting or messaging. One who holds a phone up in front of their face while talking is in a video call. We observed each of these behaviors on various trails.

On the Timpanogos Saddle, an interesting phenomenon was observed when hikers reached the saddle. Because of the remote nature of the trailhead and the trail itself, cell phone coverage is largely nonexistent along the trail. Upon climbing up to the saddle prior to making the final ascent to the peak, one suddenly encounters cell phone coverage. Many hikers were observed to participate in behavior consistent with making phone calls, taking pictures or selfies, and possibly texting or posting to social media.

At Delicate Arch, a couple who were near were observed to make phone calls with others who appeared to be members of their family or friends group in order to coordinate plans for other hikes and meet-ups later in the day.

At the Y Mountain Trail, an individual reached the top and used her phone in a manner seemingly consistent with a video call or taking a selfie to post or send, including attempting to include herself and her dog in the frame and talking to the phone as though somebody were listening at the other end.

Civilized World Concerns

This particular theme bumps up against the limitations of observation. It is easy to observe individuals communicating or otherwise using a phone when on-trail. It is harder to know whether such use involves an overriding Civilized world concern or is merely an act of *Staying Connected*. We did not observe any behavior which could reliably be classified within this theme.

Enhancing the Natural World

As previously mentioned, the Y Mountain trail presented the highest instance of headphone use, which fits into this theme. These were largely earbuds, some wired and some wireless, although there was at least one instance of larger on-the-ear or over-the-ear headphones observed. Many individuals were seen to interact with their phones briefly at the trailhead here, perhaps cueing up a playlist before beginning their hike. This is consistent with responses which mentioned music as a motivator, since behavior observed on this trail was most often consistent with exercising.

Using navigation, maps, and guidebooks was another behavior mentioned in our survey which is a part of *Enhancing the Natural World*. On the Landscape Arch trail, we observed a small group of hikers gathered around one individual who was scrolling up and down as they all observed what appeared to be a digital guidebook app.

Bringing Part of the Natural World Back

The most common activity in this theme is photography. At Delicate Arch, photography was one of the most visible and frequent activities, which makes sense given its popularity. Many individuals were observed to use both smartphones and separate cameras, as well as selfie sticks and action cameras.

Interestingly, several couples or groups of people seemed to experience the arch mainly through photography as opposed to spending time looking at the landscape with the naked eye. This included a couple who jostled smartphones and an action camera on a selfie stick between them, taking multiple photos and videos, and continuing to carry these items in their hands when needing to step up the approximatly 1m high rim of rock at the edge of the bowl surrounding the arch when they left. This couple was not observed to look at the arch for any amount of time with their naked eyes.

Another group of young female tourists, each in a different colored dress, spent a large amount of time taking photos of one another and handing phones back and forth, appearing to be reviewing these photos. These individuals, however, did eventually put cameras away and sat talking and observing the arch.

Maintaining and Ignoring the Boundary

The two other axial themes of the *Two Worlds* model were harder to readily observe. *Maintaining the Boundary* is hard to see, because observers are unable to discern between an individual who does not carry a phone, one who carries one but chooses not to use it, or one who is merely not currently using it.

Similarly, we cannot observe whether or not a person is ignoring the boundary by bringing a smartphone because they simply always bring a smartphone wherever they go. Thus *Ignoring the Boundary* is essentially unobservable without interviewing the hiker.

5.3 Discussion

We augmented results from our open-ended survey by conducting further qualitative inquiry. This triangulation led to better overall understanding of hikers and their preferences. Analysis of data gathered during interviews with 16 hikers uncovered a new theme: *Curation*, in which individuals carefully select technology for use on the trail. Consideration of this theme an its connection to the *Two Worlds* model led to its inclusion as an axial theme within the model and a more nuanced understanding of the model and what it encompasses.

Observations validated reported usage of technology, with on-trail behavior being largely consistent with types and relative frequency of usage reported by individuals in survey and interview studies. Behaviors were observed which fit the new new *Curation* axial theme, and individual themes within the *Bridging the Boundary* axial theme, although *Maintaining* and *Ignoring* were more difficult to observe.

5.3.1 Validating and Extending the ***Two Worlds*** Model

As detailed in Chapter 4, qualitative analysis of short-answer survey data led to a *Two Worlds* model of individuals' technology decisions when hiking, including behaviors described as *Bridging*, *Maintaining*, and *Ignoring* the boundary between worlds. The development of this model followed the constant comparative method, in which results are constantly cross-checked with each other in order to test the validity of findings and ensure that one's understanding is as comprehensive and correct as possible [61].

Initial work in this method is inductive: one works from the data upwards in developing codes, themes, and axial themes. Analysis detailed in Chapter 4 follows this approach. In the work detailed in this chapter we also performed a deductive application of the model, working downwards in applying the model to new data and attempting to determine whether it fits. Deductive application of a model, testing for fit, is a useful validation step and serves to help establish a model's accuracy.

In deductively applying the *Two Worlds* model to data gathered in interviews and observations, we found that it fit in terms of descriptive and explanatory power. In other words, themes identified as important in the model were evident in interview data, and the model helped explain individuals' approaches to decisions regarding technology use when hiking.

Inductive analysis of interview data also uncovered the new theme of *Curation*. Further discussion and consideration of this *Curation* theme and its components, as well as the axial themes and themes within the *Two Worlds* model led to the expansion of our model to embrace *Curation* as a new axial theme, as well as to include the axial themes *Safety* and *Technical Considerations* which were present in survey data but previously considered unrelated to the model.

The critical consideration that led to the changes in the model was the notion that hikers use technology for more than simply addressing the *boundary* between worlds. In this expanded model, individuals are cognizant of the differences between the Civilized and Natural worlds and of the positives and negatives inherent in crossing the boundary to enter the Natural world when going hiking. They use technology in various ways in order to address the *boundary* and the *differences* between these worlds. The axial themes in this broader *Two Worlds* are:

- **Bridging, Maintaining, Ignoring:** as before, individuals make decisions with regards to the boundary and technology's ability to bridge it
- **Curation:** individuals carefully and selectively adopt and adapt technology in support of their goals and purposes surrounding hiking
- **Safety:** individuals use technology in the Natural world in order to ensure greater safety for themselves and others and/or to be prepared for emergencies

- **Technical Considerations:** individuals are mindful of the environmental and technical challenges the Natural world poses to computers and make technology decisions respecting this knowledge

Each of these axial themes encompasses other themes, as previously outlined. Axial themes in the model also interconnect in various ways, and individuals' decisions are informed by their own complex attitudes regarding the worlds, the boundary, and these axial themes.

5.3.2 Triangulation

In quantitative work outlined in Chapter 3, we found correlation between individuals' hiking preferences and their preferences for carrying/using technology when hiking. In our analysis of interview data, we derived a new axial theme within the *Two Worlds* model: *Curation*. This theme explains that individuals make decisions regarding their carrying and use of technology when hiking as part of a curation process in order to meet their goals and intents for hiking.

This illustrates the benefit of our adoption of an explanatory sequential study design, wherein interesting ideas and questions uncovered in initial quantitative inquiry are further explored through qualitative study. Agreement between results of various data gathering activities also serves to strengthen the internal validity of our results.

The addition of these axial themes broadens the *Two Worlds* model to be inclusive of all of the data gathered in our qualitative inquiry, which increases its descriptive and explanatory power. The occurrence of many of the themes from our qualitative survey in interview and observation data also serves to strengthen the validity of the model. Upon this further data-gathering triangulation and iteration on our model's scope, boundaries, and meaning, we posit that the *Two Worlds* model is more mature and complete. We look forward to its application and further validation and maturation over time through the work of ourselves and others.

5.3.3 Conclusion

Further qualitative inquiry through interviews and observations led to validation and refinement of our *Two Worlds* model through deductive application of the model to new data as well as inductive analysis leading to the addition of *Curation* as a new axial theme, as well as two other axial themes from previous survey data. It also served to confirm results regarding the technology being carried and used on the trail and general usage patterns, as well as clarifying the frequency, location, and amount of use. These additions broaden and bolster the completeness and validity of the model. We next discuss a carefully-considered vision for computing in outdoor recreation which will inform future work in designing and implementing devices, systems, and applications.

5.3.4 Contribution

This work expands on the *Theoretical* contribution discussed in the previous chapter. Wobbrock and Kientz state the following regarding such contributions:

> Theoretical research contributions are evaluated based on their novelty, soundness, and power to describe, predict, and explain. A theory that accounts well for observed data from a specific situation but has no ability to generalize to new situations is of limited use. Conversely, a theory that is so broad it can account for just about anything probably does not contain any true descriptive power. [86]

In particular, the results detailed in this chapter help to increase the *predictive* and *explanatory* power and shore up the *soundness* of our *Two Worlds* model, which appears to "[account] well for observed data" as gathered in our surveys, interviews, and observations. This is especially true given the expansion of the model to include the new *Curation* axial theme as well as the axial themes of *Safety* and *Technical Considerations* encountered in survey data.

Chapter 6

Phase 2: HCI Outdoors: An Envisionment

The previous 3 chapters described Phase 1 of our work, a mixed-methods study designed to create a theory explaining what hikers do with interactive computing while hiking and why. Through this work we have developed a *Two Worlds* model describing individuals' attitude toward technology use when hiking. This model posits that hikers, mindful of crossing the boundary between the Civilized and Natural worlds when going hiking, make decisions in various areas with regards to the worlds and the boundary.

Phase 1 grounds our work in the present. In this chapter we describe Phase 2, which seeks to envision and begin exploring the future of computing in outdoor recreation. The two phases of our work are complementary, serving to strengthen one another and work together to provide a launch pad for future research.

The goal of Phase 2 is to develop and begin to realize a vision regarding computing's proper place in outdoor recreation. This vision seeks to imagine the future of HCI Outdoors and navigate the tension between the desire to include mobile computing, which connects us with the Civilized world, and the desire to disconnect while in the outdoors.

In seeking to accomplish our goals, we take into account social norms regarding time spent outdoors, philosophical discussions of the value of time in the wilderness, ideas from HCI, and research in social science about the benefits of time spent in natural settings.

We anticipate that the combination of our *Two Worlds* model with our vision will inform a design approach which is forward-looking while being grounded in present realities.

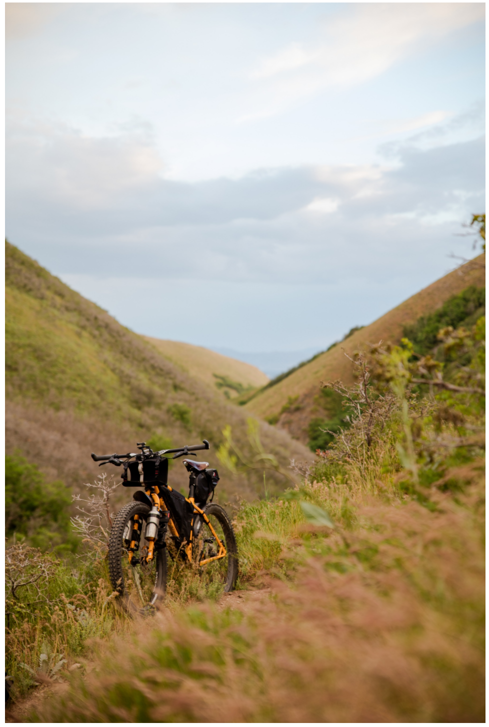


Figure 6.1: A mountain bike loaded for touring. Existing technology already seeks to augment such gear with useful technology, and we envision a future where perhaps almost all of the gear in this photo would be computing-enabled.

This chapter represents an *envisionment*, a type of *artifact* contribution. These contributions are evaluated based on their portrayal and on how they negotiate trade-offs and competing priorities [86].

6.1 Principles

This vision is based on three principles:

- Time spent outdoors is good for individuals and society
- Computing can play a valuable role in enhancing, encouraging, and enabling time spent outdoors
- In outdoor activities, human-nature interaction holds priority over human-computer interaction

After a brief summary of our vision we will discuss each principle in turn and lay out some guidelines which spring from the latter two. These guidelines are intended to help navigate the tension between staying connected through technology and disconnecting from everyday pressures. We do so with the intent of allowing computing to fill meaningful roles while respecting human-nature interaction as the primary motivation of outdoor recreation.

We envision a world in which computing discretely exists around us when we are outdoors. In this world, computing observes us and the world around us and responds in meaningful and useful ways, all while remaining largely at the periphery of our experience. It will augment or be integrated into existing outdoor gear, neatly blending with the physical world. It will not demand attention but will be available when needed. It will cater to individuals' human-computer interaction preferences while encouraging deeper human-nature interaction. We believe that computing which follows this vision can enhance, enable, and encourage outdoor recreation without detracting from human-nature interaction.

As an illustration, we present an example of an outdoor recreationalist and her hypothesized experience using compute-enabled gear. This is presented as an introduction here and then as continuing vignettes relating to each portion of the vision. We italicize these to make them easier to differentiate.

Kerstin is going backpacking for 10 days. Her goal is to disconnect for a time and to recuperate from grad school after her recent graduation. She is concerned about safety but is an experienced hiker and backpacker and knows the trail she is following well. She is carrying normal backpacking gear including a pack, tent, boots, and trekking poles, some of which is augmented by computing. She is also carrying food and water for her journey and knows where to source more along the way as necessary. She wants to spend time in reflection and finds that recording her experience helps her reflect more deeply while she is on the trail.

6.2 Time Spent Outdoors Is Good for Individuals and Society

As detailed by Nash in *Wilderness and the American Mind*, undeveloped wilderness was at one time considered a place of darkness and danger but over time as technology and human understanding advanced, it began to be prized and even protected [67]. A central figure in American culture as it relates to wilderness is Henry David Thoreau, who famously spent two years, two months, and two days in a small cabin which he built near Walden Pond in Concord, Massachusetts, an experience which he documented in the book *Walden* [78]. Thoreau expresses the following sentiment:

> I went to the woods because I wished to live deliberately, to front only the essential facts of life, and see if I could not learn what it had to teach, and not, when I came to die, discover that I had not lived. –Thoreau, *Walden*

Many individuals have since and continue to feel that time in nature is a way to truly 'live.' Naturalist John Muir, another influential figure in American wilderness and preservation philosophy, wrote in 1901:

> Climb the mountains and get their good tidings. Nature's peace will flow into you as sunshine flows into trees. The winds will blow their own freshness into you, and the storms their energy, while cares will drop off like autumn leaves. –Muir, *Our National Parks* [66]

Robert Marshall, a pioneering forester, wrote in 1934:

> In a world over-run with split second schedules, physical uncertainty and man-made superficiality ... life's most splendid moments come in the opportunity to enjoy undefiled nature. [59].

Such devotion to the natural world continues to be popular with individuals in the United States. The Outdoor Foundation reports that 44.9 million Americans participated in at least one hiking trip in 2017 [76]–more than the 38.9 million people who attended both Disneyland and Disney's Magic Kingdom in the same year [9].

Individuals, families, and society at large benefit from time spent in natural settings. In their book *The Experience of Nature: A Psychological Perspective* [43], Stephen and Rachel Kaplan discuss the notion of *directed attention*, drawn from earlier work by William James [35]. The Kaplans pioneered the field of Attention Restoration Theory as an explanation for why time in nature restores people. In this theory, directed attention is a mental resource individuals expend when focusing on a task, particularly tasks that may not be naturally fascinating. Eventually, directed attention becomes depleted, leading to directed attention fatigue. Inhibition is a key factor in maintaining directed attention because it allows individuals to avoid distraction and stay on task. Directed attention fatigue leads to reduced inhibition, resulting in suboptimal executive function, irritability, impulsiveness, and irrationality [43].

The Kaplans outline several factors necessary to create a *restorative environment*–an environment in which directed attention can be restored. These factors are:

- Being Away - the restorative environment must represent a break from one's typical environment, and in particular from whatever activities deplete directed attention
- Extent - the restorative environment must "be rich enough and coherent enough so that it constitutes a whole other world" [44]
- Compatibility - the restorative environment should be compatible with one's goals and purposes
- Soft Fascination - the restorative environment should be naturally fascinating, capturing one's attention without requiring effort

Citing results from numerous studies, the Kaplans conclude that nature and natural settings are ideal restorative environments, meeting each of these requirements.

As we consider the role of interactive computing in outdoor recreation experiences, we can use the factors of a restorative environment as guidance. For example, how does smartphone use impact the feeling of “being away” from the daily routine or the sense of “soft fascination” in a new setting?

Attention restoration theory predicts that Kerstin’s trip will put her in an environment that allows her much-needed time to relax and reflect on her experiences in grad school as she closes one chapter of her life and prepares to begin a new one. She hopes that talking through and recording some of her thoughts and feelings along the way will help her in this process. She also hopes that pairing some of these recordings with video or still pictures will allow her to revisit and remember some of these thoughts and feelings more vividly in the future.

6.3 Computing Enhances, Enables, and Encourages Outdoor Recreation

Although computing is not a traditional part of outdoor recreation, technology definitely is. Recreationalists use a vast array of technology from relatively simple items such as boots or shoes to complex systems such as suspension linkages for mountain bikes. Technology has long belonged in the outdoors and boasts a rich history of enhancing, enabling, and encouraging individuals to participate in outdoor activities. Mobile computing technology allows computing to begin to do the same, allowing individuals to bring compute-enabled systems, devices, and gear into the outdoors. This principle—*Computing Enhances, Enables, and Encourages Outdoor Recreation*—embraces this future and outlines our vision of how this future might look.

6.3.1 Computing Is All Around Us in the Outdoors

Individuals already carry computers everywhere, including outdoors. This is clear from the results of our quantitative survey, in which 95% of respondents (n. 1002) indicated that they prefer to bring their cell phone when hiking. HCI Outdoors research and the growing community around this research are, in part, a response to this reality.

Computers continue to proliferate in all areas of modern life. Research and industry movements such as Internet of Things (IoT) and Body Area Networks (BANs) explore ways that computing can be leveraged in order to support and enhance daily life (IoT) and health and wellness (BANs). Our vision embraces a similar notion; however, with much less collection and sharing of data than is typical of IoT [10, 12, 29] and without the health and wellness emphasis of BANs [18, 63].

We envision the number of outdoor computing devices or compute-enabled pieces of gear rising in the future, until computing is even surrounding individuals outdoors. Clearly this does not mean individuals are staring at tiny screens on every surface. Rather, computing will be integrated into or mated with existing gear in ways that augment their functionality, add new but congruent functionality, support other intents, and/or simplify interaction with technology.

We note that "all around us" refers to computing carried into, and out of, the natural environment by the individual. We encourage efforts to leave the natural environment as it is, rather than to introduce more man-made objects. However, it may prove useful to augment existing man-made structures and objects in the natural environment with computing in support of recreation. For instance, a map board at a trailhead could allow individuals to tap their phone on it and download a map via NFC.

6.3.2 Computers Observe and Act

Computing does not need user input in order to be useful. The computer in a modern car is constantly working to maintain fuel efficiency, enable safe traction, lower emissions, and perform many other functions, all without any conscious input from the driver. The entire idea of IoT is built on embedded systems that work with little to no user input.

However, many of the interfaces on smartphones—the default computing device carried by individuals in the outdoors—are designed specifically to keep our attention. In fact, many apps and websites draw their revenue largely or entirely from advertising, which leads to interfaces which are designed to capture and keep users' attention [56].

In contrast, one goal of many outdoor recreation activities is to spend time in a natural setting and set aside distractions while doing so. Navigating this tension, as indicated before, is an imperative. As stated in the third principle, human-nature interaction takes precedence over any form of human-computer interaction while outdoors. This guideline is designed to help ease this tension by applying the notion that computers can act on our behalf without requiring user input.

This guideline expects devices, systems, and compute-enabled gear to gather data from the environment and from the user, to make judgments, and to execute actions in support of the user and their goals. This should all happen with little to no interaction from the user. This operates much like IoT and BAN setups; however, in our approach individuals' data should only be seen by the user's device, never shared to the wider world. Furthermore, data should only be stored long enough to observe and act on it, and it should not be stored long-term either locally or in the cloud except as specifically requested by the user. This is a crucial difference from IoT and BAN approaches, where data collection and sharing are core tenets.

6.3.3 Smartphone as a Hub

A central aspect of this vision involves using an individual's smartphone as a hub during outdoor activities. Individuals overwhelmingly choose to carry a phone when hiking, most of which are smartphones. A typical modern smartphone's capabilities include numerous sensors, multiple types of wireless connectivity, a camera, an LED light, and a speaker among others.

Using the smartphone as a hub involves using the phone in WiFi hub mode, allowing other systems and devices to connect. By doing this connected devices and systems can easily communicate with not only the phone, but with other devices and systems as well. They may also take advantage of the phone's capabilities in support of their own roles. This also allows these devices and systems to be streamlined, relying on the phone for connectivity and other services, and incorporating only that functionality which is necessary to their particular roles.

While leveraging the phone's capabilities, devices and systems can also interact with each other to increase functionality and/or usability. Inputs and outputs from different devices and systems, as well as data from the phone, can be paired in ways that create a better overall system.

Using the smartphone as a hub means that input and output can be simplified, moving to more convenient and less obtrusive locations. This means individuals interact less frequently, if at all, with the phone directly, allowing them to avoid distraction from notifications or other features of the phone.

Before she left home, Kerstin curated a selection of compute-enabled devices to bring. She brought only those items that fit her goals for this trip. Because this is not a fitness training outing, she did not bring her heart rate monitor and will not record her walking pace for this trip. Those details would be a distraction.

She decided to bring several compute-enabled devices and systems. These include her smartphone, trekking poles, backpack, and a hat.

Upon arriving at the trailhead, Kerstin gathers her gear and begins to prepare to hike. She starts an app on her phone which will record her progress, although this is not for her. Every thirty seconds the app updates her location, allowing loved ones to see that she is safely making progress along the trail. This app supports her goal of staying safe. The app also places her phone into WiFi hub mode, allowing other gear to connect to it.

Kerstin puts on her hat. Although it looks like a normal hat, it includes a built-in camera. Before stepping onto the trail, Kerstin presses a button on her trekking pole, triggering her camera to take a picture of the trailhead and documenting the beginning of her journey.

Once on the trail, Kerstin decides to start recording her experience. She begins talking about her excitement, the trip, and her goals. As she speaks, the camera recognizes her voice and begins to record video and audio. This recording is stored in the camera and uploaded to her smartphone in the background when the camera is not in use.

When Kerstin stops for a breather, her backpack senses that she has set it down and sends an "OK" message to those observing her via her phone's app. Kerstin has the option of pulling out her phone to customize this message by sending along a photo or a brief recording from her hat-mounted camera, but she chooses to simply take in the scenery.

Stopping for the night, Kerstin sets up her tent. Removing the tent from her backpack triggers a "stopping for the night" message to be sent home, along with several photos she has taken during the day. Video she has recorded is not sent, as Kerstin has opted to keep these recordings for her own reflection. She sets her hat and trekking poles near her backpack, where they charge wirelessly from the built-in power bank, which has been charging during the day via a solar panel mounted on her pack.

6.4 Computing Respects the Primacy of Human-Nature Interaction

Individuals already carry and interact with computing devices during hiking and other outdoor activities. As outlined in the previous section, our vision involves even more computing devices and compute-enabled gear. However, this does not translate to more human-computer interaction. We envision computing which is designed to be increasingly hands-off and allows individuals to focus on their recreation, while compute-enabled gear and devices work in the background and are ready when needed.

6.4.1 Computing Fits the Physical Environment

This guideline is intended to lead to devices and systems which are more congruent with the experience of outdoor recreation in terms of functionality, form, aesthetic, and usage pattern.

In outdoor activities, selecting the right gear is very important. Individuals must consider weight, utility, safety, comfort, and other factors in deciding which gear to purchase. Activities requiring individuals to move quickly require gear that is lightweight and not cumbersome, while activities which are longer in terms of distance or time require gear which is somewhat heavier and more cumbersome as well as a greater variety of gear.

Computing devices and systems need not become another decision point. Instead, computing should augment or be integrated with existing gear. We envision existing gear being augmented with computing in order to improve its efficacy, safety, durability, or usability. Devices and systems which do not integrate directly with existing gear can be designed to be placed as seamlessly as possible onto or into existing gear, thus providing input, output, and other functionality without becoming cumbersome, unwieldy, or intrusive.

The future of computing-enabled outdoor recreation gear should, on the surface, appear like gear in use today. We do not seek a future which looks like “George Jetson goes camping.” This provides an experience which is more in-line with individuals’ existing experience with human-nature interaction.

6.4.2 Computing Lives on the Periphery

With our guidelines *Smartphone As a Hub* and *Computing Fits the Physical Environment*, we have already specified computing’s place as being very much out of sight and out of mind in outdoor recreation. This guideline is meant to expand on those. It concerns the physical placement of computing in outdoor recreation as well as the interactions users take with computing. Figure 6.2 shows a hiker enjoying a mountain vista. In our vision, this image would be essentially identical–computing would exist within the gear the hiker already carries.

Figure 6.2: A hiker enjoys a mountain view. Compute-enabled gear need not add to the load he is already carrying but should fit in seamlessly and augment existing gear.

Computing for outdoor recreation should not placed in a way that demands attention. Placing computing within or making it easy to attach to existing gear will help ensure it remains physically peripheral. We urge designers to adopt placement that keeps computing on the physical periphery.

While we envision devices and systems that require as little input and produce as little output as possible, some input/output (I/O) will still be necessary. It should, however, be done simply and unobtrusively. A touchscreen is not necessary when a button, knob, or other physical control will suffice. Audible or visible notifications are likely not necessary except in the most urgent cases, such as safety concerns. Rarely should computing in the outdoors demand an individual's attention through I/O.

As with other guidelines, the goal is for individuals to benefit from computing devices and systems while allowing them to focus on the outdoor experience.

6.4.3 Computing Encourages More Human-Nature Interaction

Finally, computing should attempt, insofar as it is possible, to encourage individuals to engage more and more deeply with nature. Much of this is accomplished with our other guidelines which seek to avoid computing's intrusion on one's focus on the natural world. However, we should also seek to actively encourage individuals to engage more with the natural world. This may take the form of disabling certain functionality or apps on a smartphone when in "outdoors mode," alerting the individual to facets of the natural world they may have missed otherwise, or allowing for graceful transitions wherein frequent actions taken by the user are made to be less interaction-heavy and more natural, or possibly even automatic.

On the trail, Kerstin does not notice that she is carrying compute-enabled gear. Her backpack fits and functions much like any other backpack. Her trekking poles do exactly what trekking poles are meant to do. Her hat shades her from the sun. When she needs the extra functionality of these devices, they are there. When she wants to think out loud and record her thoughts, she does so. When she presses the button on her trekking pole, it takes a picture. Her phone does not produce notifications or sounds of any kind. Kerstin is free to focus on her experience without unwanted external distraction.

6.5 Prototypes: Realizing/Illustrating our Vision

Envisionments in HCI have a history of realization. Researchers develop their vision regarding some aspect of the future of computing, and then create prototypes which embody this vision, realizing it and illustrating its core principles and salient ideas, as well as areas for future design and research. Ishii's *Tangible Bits* and Weiser's *The Computer for the 21st Century* are examples of work which follow this pattern [33, 84].

We have developed and built four prototypes which realize and illustrate different aspects of our vision. These include:

- A water bottle that tracks how much water a hiker has had over time and notifies the hiker when they should drink more
- A small box that includes a button, small OLED screen, and RGB LED
- A cap-mounted camera
- An app—*TrackMe*—that keeps loved ones at home up-to-date with estimates of when the hiker will return

Each of these devices and systems serves a specific purpose for the hiker and is intended to illustrate a portion of our vision and explore a different point within the space defined by our model.

6.5.1 TrackMe App

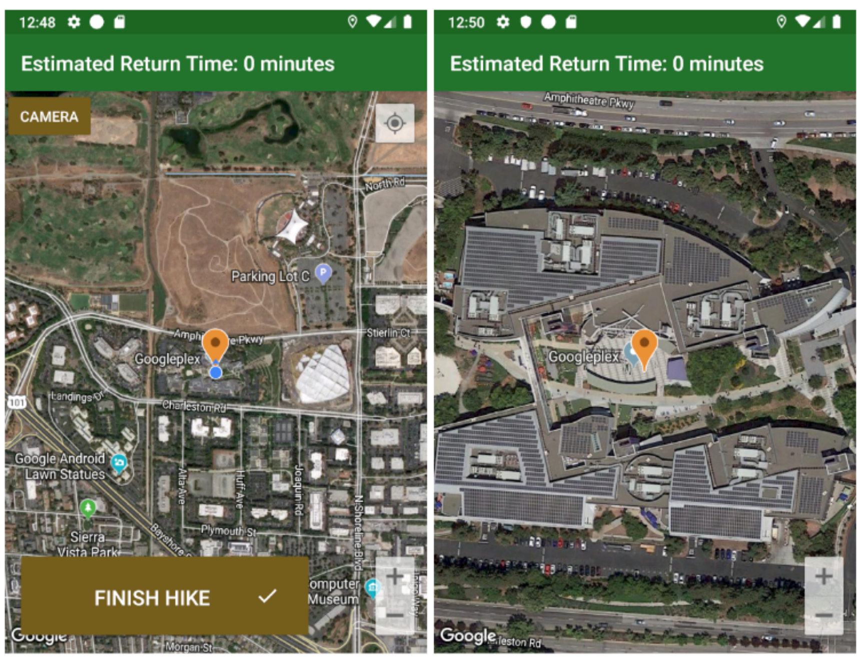


Figure 6.3: Two screenshots from the TrackMe app, depicting the view for the hiker and observer(s).

Figure 6.3 shows two screenshots from the TrackMe app. TrackMe is an app that allows a hiker's loved ones to track their movements and provides an estimated return time based on the distance hiked.

At the trailhead, the hiker starts the TrackMe app. The main screen allows the user to decide whether they want to Hike or to Observe. The hiker selects Hike. Once the app has GPS location, it begins recording and uploading GPS fixes once every 5 seconds. A map is also displayed, showing the hiker and observers the hiker's location and path traveled.

Every time a fix is recorded, it is uploaded to the cloud, where it is visible to those at home observing the hike. A new return time is also calculated.

When observers at home launch the app, they select the Observe option. The map is displayed, and they are able to see a red line which reflects the hiker's path, along with an estimate of the hiker's return time.

The app also allows the hiker to access the camera from within TrackMe. Photos taken in this way will be posted as thumbnails on the map for both the hiker and observers to see.

This app seeks to bridge the boundary by focusing on the experience for individuals at home. Thus it explores a unique area of the *Two Worlds* model space which is mainly populated at present by safety devices intended to simply notify loved ones of an individual's whereabouts and provide very basic communication, such as Spot Trackers[1] or Garmin Inreach[2]. This corner of the space is interesting and bears further exploration.

Within our vision, this app represents pushing interactions to the periphery. The only interaction that is necessary in using the app takes place at the start and finish of the hike. These interactions are at the periphery of the hike in the temporal sense. Further interaction may take place on the trail in the form of taking pictures from within the app in order to have them shared with those at home, but this is at the hiker's discretion, which is in line with the *Curation* axial theme from the *Two Worlds* model.

Figure 6.4: Our instrumented water bottle. The bottle tracks a hiker's water intake and displays a color via an RGB LED which indicates the hiker's estimated hydration level.

Water Bottle

The instrumented water bottle is intended to help the hiker stay hydrated by tracking water intake and encouraging the hiker to drink more water when necessary. The water bottle senses the amount of water it held to begin with and periodically compares how much has been consumed with an estimate of how much one should consume over a given time period when hiking. An RGB LED indicates the hydration status of the user.

The color of the LED indicates the current estimated hydration state of the hiker. Three states are represented. In each state, the water bottle displays a different color:

- Green/Good - This state means the hiker should be well-hydrated
- Yellow/OK - This represents a state where the hiker might be starting to fall behind on hydration

[1] https://www.findmespot.com/en/index.php?cid=101
[2] https://explore.garmin.com/en-US/inreach/

- Red/Danger - This represents a state where the hiker should definitely drink more water in order to catch up on staying hydrated

This water bottle represents an instance of computing observing and acting on the hiker's behalf. The goal of this device is to amplify the hiker's intent to stay hydrated and safe on the trail. Although a hiker can typically easily check visually in order to determine how much water is in their bottle, this water bottle acts in behalf of the hiker in doing so, and performs calculations to determine whether the hiker is safe given the amount of water they have (or have not) consumed.

The water bottle simplifies interaction by including no input or output apart from the RGB LED. More to this point, the water bottle can transmit its current state. This allows for the state to be communicated in other ways that are unobtrusive, such as an RGB LED placed where the hiker can more easily see it, or via haptic feedback. This allows the hiker to be peripherally aware of this calculated hydration state, rather than having to physically check the water bottle.

This water bottle is also an example of technology that augments an existing piece of gear without adding unnecessary functionality or complication of the normal usage of the gear.

Commercial water bottles which track one's daily hydration exist in various forms and with various feature sets[3]. Most such bottles are intended for daily use in regular life while ours is intended for use when hiking in particular. More pointedly, our bottle is intended to act in conjunction with the Button/OLED screen device to illustrate communicating the hydration state in the periphery via the RGB LED without the hiker needing to look at the bottle.

Figure 6.5: The head-mounted camera prototype.

Head-Mounted Camera

The head-mounted camera is mounted to a headlamp strap and can be remotely triggered. In this particular group of systems, it is triggered by pressing the button on the button/OLED box. When the button is pressed, the camera takes a picture and uploads the picture to a smartphone via WiFi. A thumbnail of the picture can also be displayed on the map in the TrackMe app where it can be seen by both the hiker and those observing.

Also, the OLED screen on the Button/OLED displays the message “PICTURE!” and briefly lights the RGB LED a different color, returning shortly to display the color representing hydration state as estimated by the water bottle.

The head-mounted camera is intended to simplify the action of taking a picture, fit the actual camera in a more easily-accessible place, and make it more congruent with one’s hiking experience. Instead of needing to take out a separate camera or phone, the hiker merely looks at their desired scene and press the button. This makes “snapping a quick photo” an even quicker process. This supports the hiker’s desire to capture a scene or moment while allowing them the freedom of doing so without pulling the phone from a pocket or backpack, and avoids the potential for distraction that comes with phone interactions. This device also

[3] For example: https://hidratespark.com/; https://drinkupbottle.com/; https://www.ozmo.io/

tacitly encourages more human-nature interaction by allowing individuals to view nature's beauty through their own eyes rather than a camera lens.

A higher-fidelity prototype might be integrated into or mount easily on a cap, and may even be able to sense when a hiker wants to take a picture by noticing when they stop to look at something. Another improvement would be the ability to dictate the particular portion of a hiker's field of vision that they would like captured, perhaps by holding up the index finger and thumb of each hand, mimicking the action of framing a photograph, and automatically capturing the area indicated by the hiker. This would avoid the situation where the hiker feels compelled to look at the photograph on their phone, which would destroy the purpose of the head-mounted camera, or where they feel the need to take many photos of the same scene to ensure they get the one they want.

Button/OLED Box

Figure 6.6: Button/OLED device.

Figure 6.6 shows the Button/OLED device. This is intended to be mounted to the hiker's walking stick, backpack strap, or some other convenient location. This device provides simple inputs and outputs and also pushes interaction to the periphery.

The OLED screen displays the current time and distance hiked. The button is set up to trigger the cap-mounted camera to take a picture. The RGB LED displays the current hydration status as measured by the instrumented water bottle. This makes the hydration status easier to see than having to look at the bottle itself, which is likely to be placed in a backpack.

This particular device is intended to provide a more general-purpose input/output device. The button could be programmed to perform any of a number of different functions, and could possibly include double-press or press-and-hold interactions to allow it to perform more than one function. The RGB LED is flexible in its ability to be lit any color, and could be used to indicate a number of different states. The small OLED screen provides for the display of a relatively large amount of information and could even be used to display simplified map information.

This device explores the notions of simplifying input and output and moving it to the periphery. Interactions with this device are intentionally simple and minimal. Input is limited to pressing the button. Output is limited to a small number of characters displayed on the OLED screen and the color of the RGB LED.

As far as the model is concerned, this device is a blank canvas that can be used in a number of different ways to support bridging, maintaining, or ignoring the boundary. In this particular setup we display the time and distance traveled as well as an indication when the user presses the button to take a picture. In a different configuration, the button may send messages back home and the OLED may display short messages from loved ones.

Placement of the device is up to the individual, but in general will likely be somewhere on the periphery: on a backpack strap, trekking pole, or similar place. The information

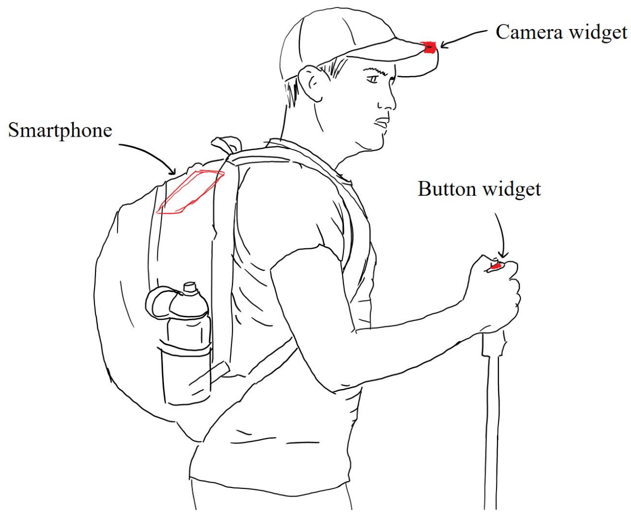


Figure 6.7: An example of a very simple HAN in which a camera widget is attached to a cap and a button is attached to a walking stick.

displayed and the functionality tied to the button are useful and meaningful within the context of a hike but not critical, meaning they fit well on the periphery.

6.6 Hiker Area Networks

As another realization of our vision, we developed a new type of system: the Hiker Area Network, or HAN. A HAN is a network comprised of various systems and devices which are interconnected via a hiker's smartphone. These components work in concert to support a hiker's goals and intents and provide helpful functionality, while remaining at the periphery of the hiking experience.

Figure 6.7 shows a simple HAN, in which a hiker has a camera widget attached to his hat, which is activated by a button on his walking stick. The prototypes discussed above represent a simple HAN. HANs are intended to be a new type of system which embodies the principles of our vision within the realm of hiking.

Characteristics of HANs are as follows:

- **Multiple Components:** A HAN is made up of multiple devices which are all interconnected. Components can be simple like a button or complex like a smartwatch. A HAN may incorporate any input or output device, sensor, or other computing device.
- **Components Fit Onto/Into Existing Gear:** Components within a HAN should be designed to easily mate with or be integrated into existing gear. Components designed in this way will require little or no modification to a hiker's existing routine in order to use them, making HANs compatible with the hiking experience.
- **Screens:** Screens should be avoided in HANs except in cases where they provide functionality not otherwise available, such as displaying a map. Insofar as possible, screens should be separate and single-purpose so as to avoid distraction.
- **WiFi Hub:** Components in a HAN communicate through the use of a smartphone in WiFi hub mode. WiFi offers ease of use and ubiquitous support of well-understood networking protocols. A smartphone also provides computing power, a camera, a broad array of built-in sensors, and connectivity options among other strengths.
- **Simple Interactions:** Interactions should be simple, such as pressing buttons, turning knobs, and simple and easy-to-learn gestures. Such interactions allow for greater focus on the hiking experience. Physical interaction should be prioritized.
- **Periphery:** HAN interaction should take place on the periphery.By placing devices, and therefore interaction, on the periphery, HANs allow hikers to attune rather than attend [85] to technology they bring with them on the trail.
- **Augment Actions:** Tolmie et al. outline a study of routines and how everyday artefacts, such as a simple front door or an alarm clock, factor into individuals' daily routines [79]. Among their conclusions is the notion that as we seek to augment artifacts digitally, we should seek to augment the actions associated with those artifacts rather than augmenting artifacts without regard to their typical use.

HANs present an interesting and particularly tight application of our vision to a particular area. We anticipate exploring the idea of HANs further, which may lead to refinement of both the idea of HANs as well as of our vision. Technical aspects of HANs in general and of our prototypes are covered in Appendix B.

6.7 Conclusion

We have outlined our vision for the role and future of computing in outdoor recreation. This vision is based on three central principles, from which several guidelines follow. It provides thought leadership about designing and building computing devices and systems for use outdoors. Given this vision and its guidelines, we hope to navigate the tension between connecting to the Civlized world and disconnecting when outdoors.

We do not discuss the technical challenges involved in building devices and systems for outdoor recreation. These include the lack of connectivity, the need for ruggedization, temperature, moisture, and other environmental challenges. While these are important considerations, we categorize them as engineering problems, separate from the design focus of our vision.

While our vision is carefully thought out and considers many sources, the value of the vision lies in practical application. Our prototypes, and the idea of HANs as a new system type, are intended to fill this role. We anticipate ourselves and others continuing to apply our vision through the design and implementation of further HANs as well as other systems for hiking and other activities.

6.8 Contribution

Our vision represents what Wobbrock and Kientz refer to as an *Envisionment*, a type of *Artifact* contribution. They state that "envisionments are evaluated by how insightful, compelling, and innovative is their portrayal. Of particular importance is how well designs negotiate trade-offs and hold competing priorities in balance. [86]" Our envisionment negotiates the inherent tension between the inclusion of mobile computing, which connects hikers with the Civilized world, and the desire to disconnect when in the outdoors. Our intent is to maintain the primacy of the human-nature interaction while providing functionality that is consistent with the hiker's intent. Other functionality is suppressed by leaving the phone in the backpack. Our envisionment also balances the priority of experiencing restoration in nature without compromising secondary priorities such as staying in touch or recording the experience. We do this by fading the computing interfaces into the background and endowing systems with the ability to act for themselves. Ultimately, the value of this envisionment will be determined by our research community. This envisionment will appear as an invited chapter in a forthcoming edited book on HCI Outdoors to be published in January 2020 [11].

Chapter 7

Discussion and Conclusion

HCI Outdoors is a small but growing community and body of research centering on the inclusion of computing in the outdoors in general. Our work fits within this scope, particularly in the area of outdoor recreation. We focused on hiking as a representative, well-understood, and popular activity. This dissertation creates new understanding of the present impact of interactive technology on hiking, explores possibilities for its future, and lays out future directions for exploration by ourselves and others.

7.1 Summary of Key Results

7.1.1 Phase 1: Empirical Theory-Building

Phase 1 of our work is detailed in Chapters 3-5 of this dissertation. This phase focused on the present, seeking to understand hikers and their hiking technology preferences and practices. Empirical work in this phase led to two broad sets of contributions.

Chapter 3 details quantitative exploration via an online survey. Results informed the creation of a set of hiker groups based on hiking preferences and, separately, a set based on technology preferences. Correlations between these preferences were also derived. Results of this study include the establishment of meaningful hiking groups, calculation of correlations between hiking and technology use preferences, and the observation of various demographic differences in preferences. In the terminology of Wobbrock and Kientz, this is an *Empirical* contribution to HCI.

Chapter 4 concerns a qualitative short-answer survey designed to further explore correlations and answer questions uncovered in our quantitative survey. In particular, this second survey sought to understand the reasons individuals carry technology when hiking. Careful thematic analysis of responses following the constant comparative method led us to a model describing hikers' adoption of technology when hiking. In this model, hikers leave the Civilized world and enter the Natural world when hiking. They choose to use technology to bridge, maintain, or ignore the boundary between these two world constructs. We call this the *Two Worlds* model.

As discussed in Chapter 5, further qualitative work informed our understanding of individuals' adoption and adaptation of technology for on-trail use. Inductive analysis of data from interviews uncovered a new axial theme, *Curation*. This axial theme was subsequently added to our *Two Worlds* model, along with the themes *Safety* and *Technical Considerations*, previously identified but left out of our model. These inclusions led to a model that is more fully-formed. Observations served to validate and clarify our previous findings regarding on-trail technology use. In particular, we found that actual time spent using technology while on-trail is typically quite short and infrequent. Chapters 4 and 5 represent a *Theoretical* contribution to HCI.

7.1.2 Phase 2: Envisionment

Phase 2 of our work, encompassing Chapter 6, is forward-looking. This chapter outlines our vision regarding the place of computing in outdoor recreation and the ways it can enhance, encourage, and enable recreation without becoming a distraction. This vision is based on social science and psychology research regarding outdoor recreation; philosophical notions about nature and wilderness; envisionments and related work from within HCI; and personal experience in the outdoors. It seeks to strike a balance in maximizing computing's ability to assist in meeting hikers' intents and goals while minimizing the potential for it to negatively impact the experience. Various prototypes, as well as the Hiker Area Network, or HAN, a new type of system, act as a realization of this vision and illustrate its principles. This is an example of an *Artifact* contribution, and specifically an *Envisionment*, within HCI.

7.2 Evaluation of Contributions

The types of HCI contributions represented by our work are *Empirical, Theoretical* and *Artifact–Envisionment*. We review each contribution type and how it is evaluated, then summarize and evaluate the contributions of this dissertation.

- Empirical contributions provide new knowledge through the gathering and analysis of data. Contributions are evaluated based on soundness of methodology and importance of results
- Theoretical contributions provide "vehicles for thought." [86] They are evaluated based on their explanatory and visionary power
- Artifacts are one of the central contribution types in HCI. Types of artifacts in this work include envisionment and system. Envisionments are evaluated based on their portrayal and "how well designs negotiate trade-offs and hold competing priorities in balance."

Empirical Contributions

New knowledge gained from our quantitative study includes the following: hiking and technology preference clusters and the correlations between them; the types and numbers of devices carried by hikers; demographic variations in hiking preferences; and, perhaps most significantly, the overwhelming preference of individuals to carry a cell phone when hiking. Each of these findings represents an important understanding regarding current technology use when hiking. The fact that 95% of individuals prefer to carry a phone when hiking is resounding indication of this research area's potential impact.

As outlined in Chapter 3, our methods for quantitative inquiry were carefully considered. Survey design was iterative and included multiple trial runs in order to find the correct constructs to measure, questions to use in doing so, and survey structure. Our selection of and approach to using Amazon Mechanical Turk was similarly methodical and informed by recognized best practices.

Theoretical Contributions

As a "vehicle for thought," [86] the *Two Worlds* model allows us to consider in what ways existing consumer and research systems and devices bridge, maintain, and ignore the boundary between worlds. It bears consideration as to whether some devices operate solely in the Natural world or whether the mere inclusion of technology is an irrevocable connection with the Civilized world. Application of the model leads to interesting questions and ideas regarding design of future systems for use in hiking and the outdoors in general.

Our interviews offer interesting vignettes that help us understand how individuals approach their decisions regarding technology use on the trail. In particular, the new axial theme of *Curation* fills in gaps in explaining *why* and *how* individuals carry and use technology while hiking. The inclusion of the *Safety* and *Technical* axial themes bring important logistical considerations within the scope of the model.

Observations lend credence to the soundness of the model, as individuals could be observed participating in behaviors which fit bridging, maintaining, and ignoring. The model's explanatory and descriptive power is shown in using it to analyze interview results and describe existing systems, while its predictive power has been partially tested in the process of designing our prototype HAN.

Artifact Contributions

In our development of a vision regarding computing's inclusion in outdoor recreation, competing priorities must be balanced. These are the interaction with mobile computing devices subsequently connecting to the Civilized world, and the desired disconnection from the Civilized world while hiking. Our vision considers a future where individuals are surrounded by computing when outdoors, yet are no more aware of it than they are of their hiking boots or backpack. The vision can also serve as a set of guideposts in navigating toward that future.

Our prototypes represent examples of the principles and guidelines within our vision, and as a whole are an example of a HAN, which is also a realization of our vision. They also probe various interesting points within the *Two Worlds* model.

Contributions: Conclusion

When taken individually, each of the contributions discussed above represent a significant and meaningful present addition to HCI. As a whole, our work also represents a solid foundation for further exploration in this fledgling area. We next consider the ways in which our work has helped to lay this foundation and set directions for future exploration.

7.3 Future Work

Apart from the present contributions of our work, our results can also inform, inspire, and direct our own and others' future work and contributions, particularly Empirical and Artifact contributions. We imagine our vision and the *Two Worlds* model as complementary pieces of a foundation to be built on by ourselves and others. Our vision informs a careful approach to building the future of computing in outdoor recreation, one which hopes for and works towards more fully integrating computing into recreation while not allowing it to take over. The *Two Worlds* model lays out territory that can be explored in this integration.

The themes, ideas, and findings of our empirical work bear further inspection and research. The demographic differences noted in our quantitative exploration warrant further inspection. Among those which may prove interesting are questions relating to how gender drives hiking preferences, whether region may play a more nuanced part in individuals' preferences, and what individuals consider "fun" when hiking.

In the intervening time since our quantitative work, others have also sought to explore different groups of individuals on the trail and their particular needs or preferences [51, 54]. While our approach is rooted in automated analysis of stated preferences via the K-Means algorithm, other approaches may also be valid. Varying approaches to identifying on-trail groups and their needs and preferences can lead to greater insights. Different groupings may prove insightful in understanding the interplay between hiking and technology preferences. Correlations between different grouping schemas may also prove informative.

Our qualitative work intentionally focused on the experiential aspects of computing, particularly individuals' preferences regarding hiking and technology use when hiking. The addition of *Safety* and *Technical Concerns* as axial themes within the *Two Worlds* model points to the value of further exploration of these more logistical aspects of the hiking and technology experience, which in concert with the experiential aspects will likely lead to better design outcomes.

Furthermore, our work explored hiking in the most general sense. Different approaches to hiking that are well-known include day-hiking, backpacking, fastpacking, thru-hiking, section hiking, and others. Exploration of the preferences and practices of participants in each of these more specialized forms of hiking may lead to further insight and inspiration.

As stated, our prototypes and the notion of HANs serve as embodiments of our vision, within the realm of hiking. However, our vision is intended to be applicable to other forms of outdoor recreation as well. New systems and system types can and should be developed which attempt to apply our vision and its principles to other activities. This may also result in the growth and maturation of our vision.

Regarding HANs themselves, there is room for further exploration as well. Areas for investigation include:

- The utility and impact of HANs with a greater or smaller number of devices
- Types of devices to include in HANs (wearables, textiles, augmented versions of existing gear, devices which are solely for input or output, etc...)

- Input/output modalities (gesture, haptic, voice, etc...)
- Experiential aspects of using HANs

As in all of HCI, further user studies are a critical aspect in understanding systems and their usability, helpfulness, ability to magnify intent, and experiential components.

Such empirical and engineering work can also build on the *Two Worlds* model, clarifying the notions and boundaries of HANs. In particular, the boundary between worlds is often unclear from both a physical and metaphorical standpoint. Better understanding of this boundary may lead to better design. Further research may also serve to push out and solidify the edges surrounding the model and the HAN concept.

Finally, it is important to identify how the results of this work do or do not extend into other outdoor activities. Any given outdoor activity has a great number of parameters that define its design space. For instance, there are activities that are quite slow-paced and/or low intensity such as fishing or camping (generally, apart from activities pursued away from the campsite). On the other hand, mountain biking and rock climbing represent activities that are very fast-paced and/or very high intensity. Activities also vary in many other ways, such as in duration (consider a brief nature walk or short hike as opposed to a thru-hike of the Appalachian Trail, a months-long undertaking).

Hiking likely falls somewhere in the middle of the intensity/duration axes. It may be that the balance between computing and nature needs to be tweaked in one direction or the other in support of an activity's parameters. It may also be that some aspects of our work fit better than others. It is important to begin exploring other activities, identifying places where our results fit, and conducting further research and design work accordingly.

7.4 Conclusion

We draw the following conclusions from our work:

- Computing is already in wide use by hikers. This is largely in the form of smartphones, although other systems and devices are also in use.
- The *Curation* theme of our *Two Worlds* model leads us to conclude that computing is largely not a distraction when hiking, but in many ways enables the experience.
- The *Two Worlds* model also provides a space which can be explored in designing and implementing new devices and systems for hiking. Consideration of the axial themes and their related themes may lead to designs which better fit hikers' desires and intents.
- Our vision as outlined in Chapter 6 can inform a design process which seeks to blaze new trails for computing in hiking and other activities, while respecting and supporting an experience which is focused on the natural world.
- Apart from the themes and questions which we identified and explored, many other interesting "side trails" present themselves for further exploration.
- In this sense, our work contributes to the present of HCI Outdoors while helping to plan for and build its future

Our work has led to important contributions which add new and valuable knowledge to the field of HCI and inform the design and building of new and interesting systems for hiking. It has also identified interesting areas of exploration, some of which have already informed the development of our *Two Worlds* model, and some of which remain largely unexplored. In this sense, our work has both blazed new trails in exploring computing's place in outdoor recreation and identified "side trails" for further exploration by ourselves and others. We eagerly anticipate the results as we and others further explore these trails.

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Appendices

Appendix A

χ^2 Residual Tables

This appendix contains χ^2 residuals plots for contingency tables which were explored but ultimately proved less than statistically significant or which were less informative than tables included in the body of the dissertation. As with other tables presented in the text, blue represents positive and red negative correlation, while the size of the square represents the relative magnitude of the correlation.

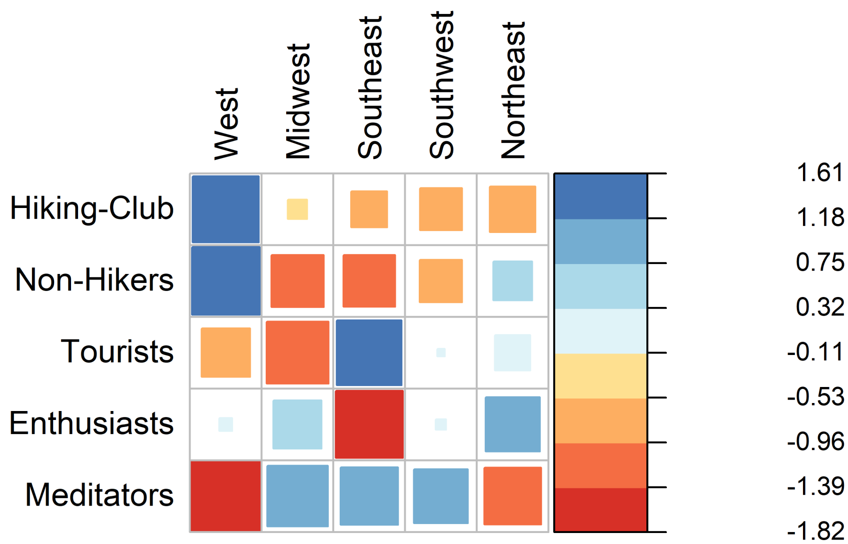

Figure A.1: χ^2 residuals for the Region/Hiking Cluster contingency table.

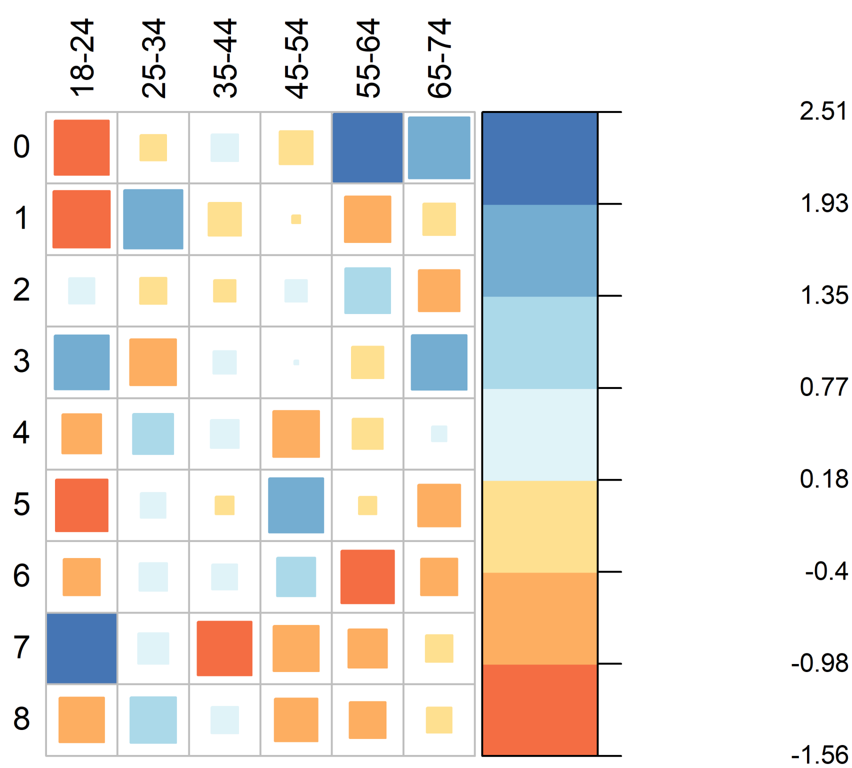

Figure A.2: χ^2 residuals for the Age/Number of Devices contingency table.

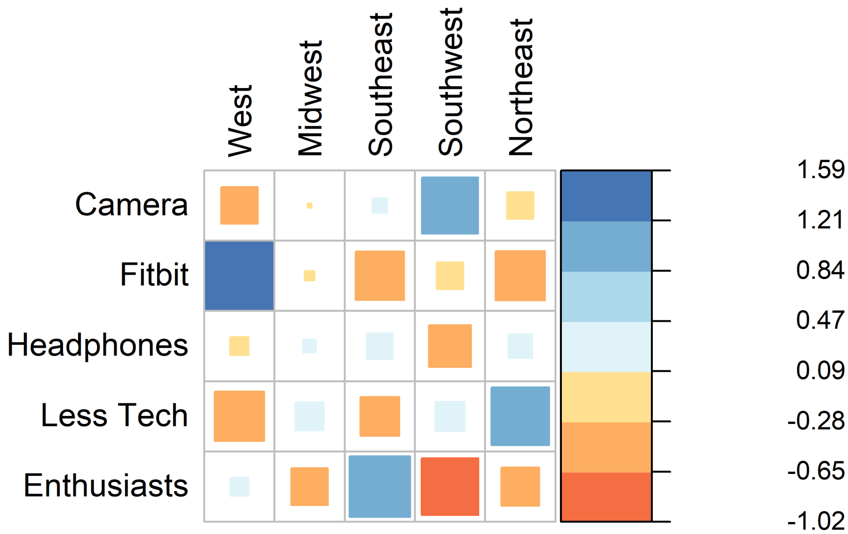

Figure A.3: χ^2 residuals for the Region/Tech Cluster contingency table.

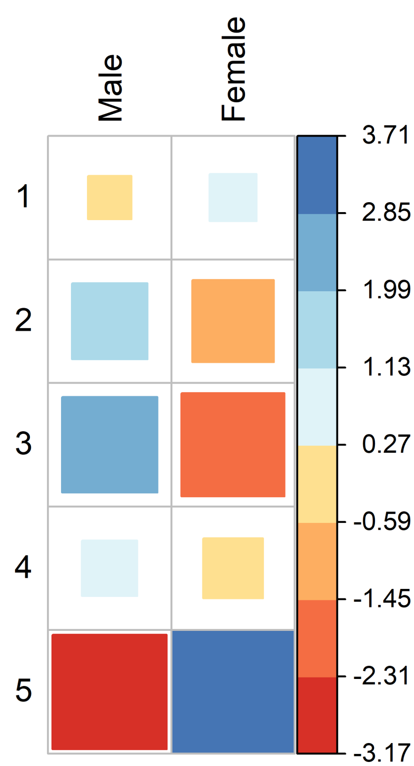

Figure A.4: χ^2 residuals for the Gender/Easy Hikes contingency table.

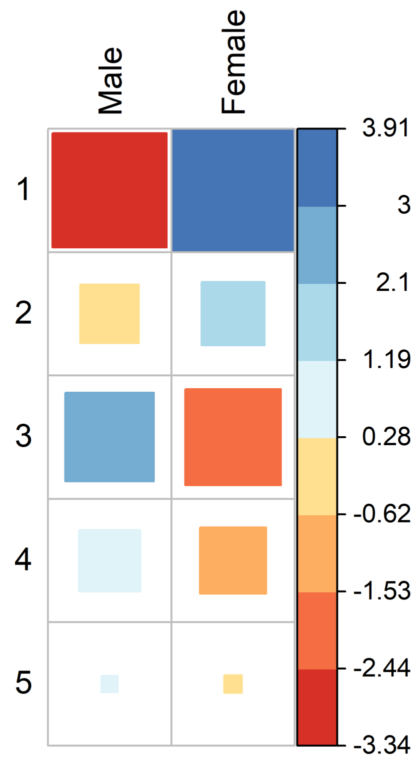

Figure A.5: χ^2 residuals for the Gender/Difficult Hikes contingency table.

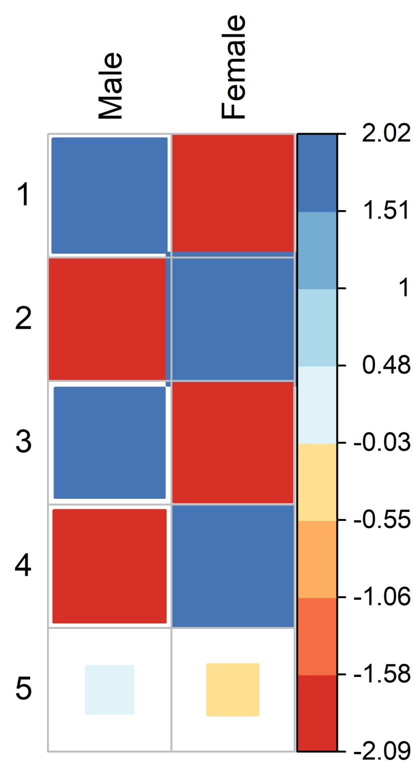

Figure A.6: χ^2 residuals for the Gender/Multi-Day Hikes contingency table.

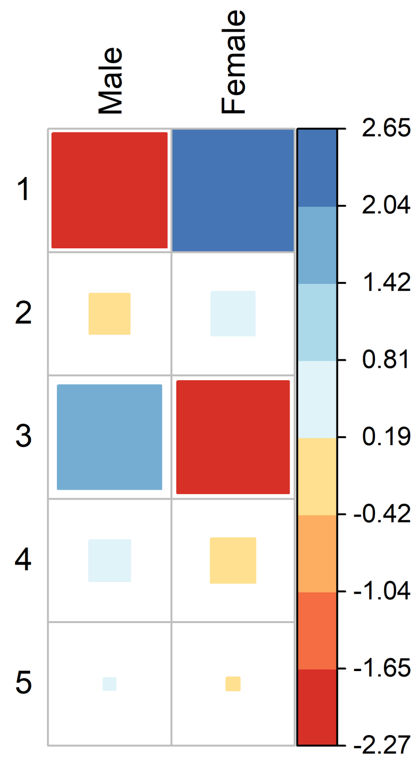

Figure A.7: χ^2 residuals for the Gender/Half-Day Hikes contingency table.

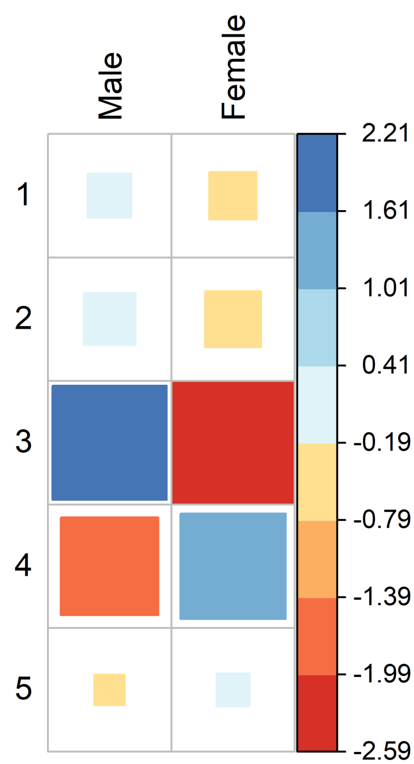

Figure A.8: χ^2 residuals for the Gender/Hiking in a Group contingency table.

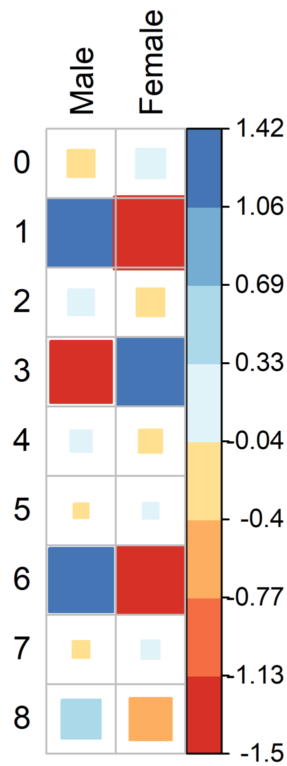

Figure A.9: χ^2 residuals for the Gender/Number of Devices contingency table.

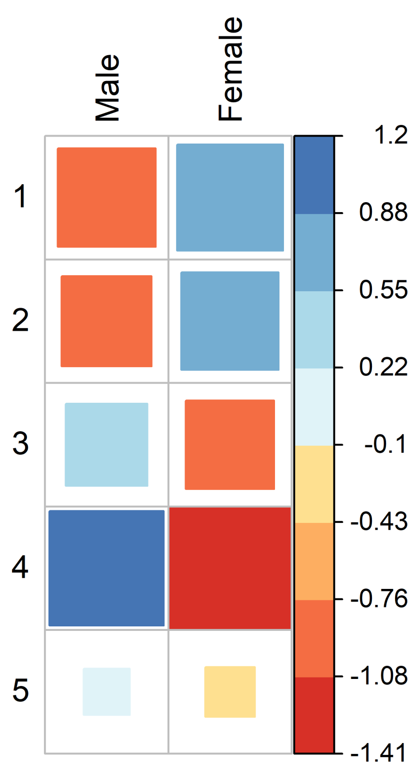

Figure A.10: χ^2 residuals for the Gender/Full Day Hikes contingency table.

Appendix B

HANs: Technical Details

This appendix contains technical details of HANs. This includes technical details and assumptions regarding HANs in general as well as specific details for ou HAN prototype.

B.1 Technical Details, Assumptions, and Limitations

As with any design or set of design guidelines, there are important technical decisions and assumptions underlying HANs. There are also limitations that should be taken into account.

B.1.1 Device Power

An important consideration for any mobile device is power, and the importance of having power is somewhat increased for the smartphone in a HAN, since other devices will be using it as a WiFi hub as well as potentially using other resources such as sensors or processing power. This increased usage of resources is likely to drain the smartphone's battery more quickly.

Portable options to charge the smartphone (and potentially other devices, especially if carried in or on a backpack) exist. The two most obvious are portable USB power banks and solar cells. An obvious concern for these (and HAN components in general) is added weight and/or space concerns. One consideration here is that in our quantitative survey, 91.3% of individuals indicated they preferred to carry between 2 and 5 devices from our list. Given this, we assume here that carrying more devices may be a slight, but not a major concern.

Two current manufacturers of USB power banks are Anker[1] and RAVPower[2]. Table B.1 shows dimensions, weight, and capacity for the smallest and largest power banks offered by each. For reference, two phones used in our development and testing of a prototype HAN—the Google Pixel 2 and Google Pixel 2 XL—are included. Even given inefficiencies and other noise in the battery charging and discharge system, the battery pack with the least capacity would still be enough to recharge one of these phones at least once.

[1]https://www.anker.com
[2]https://www.ravpower.com

Manufacturer	Dimensions	Weight	Capacity (mAh)
Anker	5.0in x 2.5in x 0.4in	4.2 oz	5000 mAh
Anker	6.5in x 2.4in x 0.9in	13 oz	20100 mAh
RAVPower	3.54in x 0.98in x 1.57in	4.1 oz	6700 mAh
RAVPower	6.9in x 3.0in x 1.0in	17.5oz	32000 mAh
Pixel 2	5.74 x 2.74 x 0.31in	5.04oz	2700 mAh
Pixel 2 XL	6.22 x 3.02 x 0.31in	6.17oz	3350 mAh

Table B.1: Dimensions, wight, and capacity for the smallest and largest power banks offered by Anker and RAVPower. Pixel 2 and Pixel 2 XL phones used in testing included for reference.

Considering solar panels, GoalZero[3] is a relatively well-known manufacturer of portable solar power panels and devices. As of writing, their smallest panel is 9x1.5x6.5 in when folded, 16.2oz, and is rated for 7W, or 1400 mAh generated in one hour at 5V. Their largest foldable panel is 8.5x13x1in when folded, 2.5lbs, and is rated for 20W, or 4000 mAh in one hour at 5V (when used unfolded).

We compare these numbers to phone battery life estimates. The Pixel 2 battery "[lasted] all day with moderate use" in a test for an online review[4]. Assuming somewhere between 8 and 16 hours of time awake and using the phone, the phone in this test used between 168.75 and 337.5 mAh of charge per hour. Even the more conservative of these estimates falls well below the rated 1400 mAh of even the smallest solar panel currently offered by GoalZero.

Assuming an even more aggressive average draw of 500 mAh by the phone when used in a HAN, we calculate the Pixel 2 lasting 5.4 hours on its own. With the smallest power bank, this is extended to 15.4 hours, and with the solar panel, depending on weather and foliage conditions, it may be possible to keep the smartphone running indefinitely.

In addition to these, there are also backpacks which come with solar panels attached, and often also include portable power banks or at least allow for their use. Such a pack would be an excellent fit for a HAN, and we used one in our testing of our prototype HAN. Details regarding its use and test results will be given in the section regarding our prototype.

B.1.2 Connectivity and Commmunication

An important aspect of a HAN's design is how communication takes place between components. We offer no specification regarding this engineering decision apart from specifying using WiFi hub mode on the phone to facilitate TCP/IP communication. We choose to leave further

[3]https://www.goalzero.com/
[4]https://www.techradar.com/reviews/google-pixel-2-review/3

decisions to designers and engineers. Communication logic between HAN components is to be designed and implemented for now on a case-by-case basis.

In designing our prototype HAN, we considered a few methods. These included having a central hub app that runs on the smartphone and routes communication between devices, or giving each device a static IP and hard-coding these into socket communication code. We also considered implementations of web servers for Android which would allow for a web service to be run on the phone.

Our prototype HAN was designed assuming cellular data connectivity. Such connectivity is a strong benefit to future HAN designs, given the opportunity to gather useful data such as map tiles, weather information, digital guidebooks, or even first aid help, and such HAN designs will suffer lack of functionality in cases where coverage is not available. However we do note that HANs can be designed and function in many useful ways without cellular data, as a smartphone's WiFi hub can function whether there is an active connection to the Internet or not. Further, certain data which is less time-sensitive, such as map tiles, guidebook info, and first aid info, can be downloaded beforehand and then used on the hike even in the absence of a cellular data connection.

B.1.3 Limitations

Limitations of HANs as presently defined include both technical considerations and certain aspects for which we do not offer any design guidance. Among these are the choice of WiFi, safety considerations, environmental challenges, and cellular connectivity or lack thereof. We discuss these briefly.

In hiking, as in other outdoor recreation activities, the outdoor environment presents many challenges to computing and technology in general. At present, HANs do not attempt to address these challenges. Increasing the number of electronic components carried in the outdoors increases the likelihood of physical, water, or other damage. Designers will have need of guidance in approaching these challenges, however the goal of HANs is to focus on the experiential aspects of designing systems for use in hiking, leaving environmental challenges to others.

Although safety was a frequent and important consideration for many individuals in our short-answer survey during Phase 1, we chose with further Phase 1 research as well as with HANs to focus on experiential aspects of hiking. This is not to say that safety does not relate to HANs or their design or implementation. Designers may wish to include safety features in their HANs or even design an entire HAN around increasing hiker safety. We merely leave such decisions in the hands of the individual designer.

In our initial approach to HANs and our prototype, we have opted to use WiFi for reasons previously outlined, including simplicity, ubiquity, the ability to use the phone as a hub, and ease of programming. This does not rule out other standards for use in other HANs or as a future standard for HANs in general. Bluetooth in particular offers lower power consumption and relative ease of connectivity, as well as ever-increasing availability and usability from a consumer as well as a developer standpoint. BLE, Bluetooth Low-Energy may also be a good fit for certain applications. Further prototyping and testing can help to suss out best directions for the future.

Our guidelines for HANs also offer no guidance to designers regarding cellular connectivity or lack thereof. As discussed, our prototype HAN includes components which can only function with such connectivity. It's also quite conceivable that many functional HANs could be built without this requirement. We leave it to designers to consider system and user needs in determining how best to plan for connectivity or lack thereof.

B.1.4 Technical Details

We describe implementation details for each component of our prototype HAN, including parts listings and description of code functionality.

Water Bottle

Parts List:

- Raspberry Pi Zero W
- Adafruit ADS1015 12-Bit ADC (Analog-Digital Converter) Breakout
- Milone Technologies 5” eTape Liquid Level Sensor
- Common anode RGB LED
- Adafruit PowerBoost 500 Charger
- Commodity switch
- LiPo battery
- Wires and resistors
- Adafruit cable gland

Overview

The Raspberry Pi provides core functionality, acting as a central hub for the liquid level sensor and providing WiFi connectivity for transmitting the hiker's current hydration state.

The Raspberry Pi runs Linux Raspbian OS. It is configured to use a static IP address so as to simplify communication with other devices. The OS is configured to connect automatically to the phone's WiFi hotspot. The file /etc/rc.local is configured to run the Python script that implements the bottle functionality on boot up.

The liquid level sensor acts as a variable resistor, with resistance changing in response to changes in hydrostatic pressure as it is immersed in more or less liquid. The Raspberry Pi allows for 3.3V logic, which is output to one side of the sensor. The voltage on the other side of the sensor is attenuated by the resistance of the sensor. One channel of the ADC is used to sample this attenuated voltage which in turn varies with the amount of water in the bottle. The ADC connects to the Raspberry Pi via I2C[5], a serial bus in common use in small electronics such as this.

Because the sensor is sensitive to pressure, it cannot be bent or twisted. To this end, it is housed within a length of 1" PVC pipe with holes and slits drilled and cut into it to allow water to enter and exit freely. An Adafruit cable gland was used to run wires through the wall of the water bottle without leakage. The entire circuit draws power from a LiPo battery pack, which is connected to the Adafruit PowerBoost 500, and charged via a 5V mini USB connection on the PowerBoost board. The PowerBoost handles voltage conversion between the 3.7V provided by the LiPo battery and the 5V required to power the Pi. The switch is used to turn the system on or off.

The common anode RGB LED used in this and the button/OLED box is an LED which is the same size as typical single-color commodity LEDs, but which includes a red, green, and blue LED. RGB LEDs come in both common cathode and common anode variants. All RGB LEDs have four leads. Common anode variants, as used in our projects, have one anode lead and three cathode leads–one each for red, green, and blue. The anode lead is connected to voltage, while the cathode leads are connected to GPOIO pins on the Raspberry Pi. The amount of voltage output to the pins connected to the cathode leads determines the intensity of light output by each of the red, green, and blue channels and in turn the resulting color of the LED. Because the Raspberry Pi cannot directly control analog voltage on its GPIO pins, PWM (pulse width modulation) is used to simulate differing voltages.

Code Details

Code for the bottle is implemented in Python using specific libraries for the Raspberry Pi GPIO functionality and the ADC. As previously outlined, the Python script is launched when the OS boots.

On startup, the script enters a loop that checks for a WiFi connection. When a WiFi connection is detected, it proceeds.

[5] https://en.wikipedia.org/wiki/I%C2%B2C

After connecting it begins a thread which opens a server socket and waits for connections. This thread handles incoming connections from the Button/OLED requesting the hiker's estimated hydration status (good/ok/bad).

The next step is calibration. When calibrating the bottle lights the RGB LED yellow for 30 seconds. It takes an average measurement over this 30 seconds of the voltage from the variable resistor presented by the liquid level sensor. It compares this reading to an average of the reading produced when it's empty (pre-recorded) and uses this to calculate a ratio of measured voltage to oz of water consumed (assuming the bottle is currently full). Upon successful calibration, the LED is set to green.

After calibration it enters a tight loop. In this loop, it waits a predetermined amount of time—15, 5, or 1 minute depending on the current estimated hydration state. After waiting, it takes a 30 second average reading of the voltage across the variable resistance presented by the liquid level sensor. Taking an average reading over time helps with sloshing water. From this reading, it calculates how much water has been consumed over the time.

It compares this calculated water consumption to an idealized amount of water intake (1.5 liters per hour). If the measured consumption is below the expected amount, a ratio is calculated. If the measured amount of water consumed is 60% of expected or less the bottle enters the BAD state. If it's 75% or less it moves to OK. Otherwise it's the GOOD state.

When requests come in from the Button/OLED, a separate thread is spun off to handle them. The current state, represented by an integer value, is returned as a response to such requests.

Head-Mounted Camera

Parts List:

- Raspberry Pi Zero W
- Raspberry Pi Camera Module
- USB Power Bank

Overview

As with the water bottle, the camera uses a Raspberry Pi, which provides WiFi and the ability to run Python scripts. The same configuration as the water bottle is used for the camera, enabling the correct script to run on startup, and using a static IP address for simple communication.

The Pi Camera is specifically designed to work with Raspberry Pi boards and connects via a proprietary ribbon cable. The Pi and camera are housed in a commercially-available case which is purpose-built to hold the Pi and place the camera in a secure and fixed position.

The Pi and camera in their case are mounted on the surface of the USB power bank. The entire assembly is mounted to a headlamp strap from which the headlamp has been removed. For this early prototype, the mounting is done using electrical tape.

Code Details

The Pi and Pi camera work in conjunction and are programmed using the *picamera* Python library. The script begins by waiting for a WiFi connection. When a connection has been established, it begins a thread that listens for incoming connections. When an incoming connection comes in, a new thread is spun off which handles the connection and incoming and outgoing communication.

Plain text messages are exchanged between other devices and the camera. The message "takephoto" triggers a new photograph being taken. When the picture is successfully recorded, the script opens a socket connection to the phone, then it uploads the image to the phone.

Button/OLED Box

Parts List:

- Adafruit HUZZAH32 ESP32 Feather Board
- Adafruit Monochrome 1.3" 128x64 OLED graphic display
- LiPo battery
- Common anode RGB LED
- Commodity pushbutton
- Wires and resistors

Overview

The HUZZAH32 is a small Arduino board and acts as the main board for the circuit. Built-in WiFi enables it to connect to the phone's WiFi hotspot as a HAN component. The Arduino platform provides for connecting both digital and analog devices, and the Arduino IDE[6] allows code to be written in C++ and easily flashed to the board's ROM. The HUZZAH32 polls the phone for a new distance and time and the water bottle for hydration status every 30 seconds, updating the OLED screen and RGB LED accordingly.

The OLED screen has a resolution of 128x64. Adafruit supplies a library to be imported into the Arduino IDE which allows for simple programming of the screen with the ability to display both graphics and text. We output text which is updated as the HUZZAH32

[6] https://www.arduino.cc/en/main/software

polls the phone for new data. The HUZZAH32 communicates with the OLED screen over SPI[7], a frequently-used communication bus in Arduino and other small electronics.

The Arduino is configured to detect button presses, which trigger a request to be sent to the camera to take a picture.

As with the RGB LED on the water bottle, the anode lead is connected to voltage, while the cathode leads are connected to digital pins on the Arduino. Delta-Sigma modulation is used to simulate differing voltages on the cathode leads.

The circuit is powered by a LiPo battery, which is charged directly by the HUZZAH32 board when connected to 5V micro USB. The OLED screen receives its power via a connection to the HUZZAH32.

Code Details

Code for the device is implemented in C++ using the Arduino IDE. Specific libraries and drivers provided by Adafruit allow for simple integration and programming of the HUZZAH32 and OLED screen.

Arduino programming is defined by two main functions: setup() is called once during the device's boot-up sequence, and loop() runs on an infinite loop as long as the device is on. The programmer can also define their own functions to use as helpers within setup() and loop()

In the setup() method, we first set up the RGB LED, which is driven using Delta-Sigma modulation in order to vary the amount of voltage seen by each cathode pin and therefore the color of the LED. Delta-Sigma modulation is a common method for translating between digital and analog signals[8].

After setting up the RGB LED, the OLED screen is started up. This is accomplished using libraries provided by Adafruit. The screen is set up to use one of several character sets provided by the Adafruit driver software for the screen. To aid legibility, we selected a relatively large character set from among those available.

WiFi connectivity is then established, which means connecting to the phone's WiFi hub, as with other components. Because the IP address of the phone's WiFi hotspot is dynamic, the address must be captured upon connection so that the box device knows what address to connect to in order to get distance and time updates from the TrackMe app.

Finally, logic is set up for the detection of button presses. In the setup() method this simply consists of setting up the correct pin on the Arduino to be used later in detecting changes when the button is pressed.

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[7] https://en.wikipedia.org/wiki/Serial$_Peripheral_Interface$

[8] https://en.wikipedia.org/wiki/Delta-sigma$_modulation$

As dictated by the overall design of the Arduino framework, after the setup() function has run, the loop() function iterates repeatedly until the device is powered off. In each iteration, the loop function:

- checks elapsed time
- calls a function which compares elapsed time to a counter
- if 30 seconds has elapsed, calls a function to send a request for a new time and distance from the phone
- does the same for hydration state, sending a request to the water bottle
- detects button presses, sending a request to the camera to take a picture when the button is pressed

When the button is pressed, it is detected in the loop and then a function is called which sends the message "takephoto" to the camera requestiong it to take a photo. The screen displays the message "PICTURE" and the LED is lit a random color briefly before being returned to its previous color.

When receiving a new time and distance update from the phone upon request, the OLED screen is updated to reflect the new values. When receiving a hydration state response from the water bottle, the RGB LED is lit to indicate this status (in the same colors as the bottle's RGB LED).

If there is an error with a request, the screen displays a message reflecting this and the next request for that particular piece of data is delayed by 2 minutes.

TrackMe App

TrackMe runs on the Android platform. It was coded using Java in Android Studio. Data is stored in a Google Firebase database. TrackMe makes uses of the GoogleMap class for displaying a map and Android location services for updating location.

When the application is launched, MapsActivity is instantiated, which contains the GoogleMap control that is used to display the map to both the hiker and the observer.

The map is displayed, and the connection is made to the Firebase database. The hiker begins the hike by pressing the Start button, and the app creates a LocationRequest object which is used as part of a request to Android location services. This object allows for the setting of a priority and and interval which in turn specify the frequency of GPS fix updates and whether the app should take priority over other apps needing to use location services. The LocationRequest object is then passed in a call to the requestLocationUpdates method, which begins the process of having the app receive location updates on a regular interval.

The interval chosen for this app is 5 seconds. This is a relatively slow interval for something like trakcing one's path. Typical GPS watches and smartphone apps often do this as much as once a second or more. We opted for 5 seconds because the purpose of this app is not to track an accurate distance and path, but to make reasonble estimates of one's return time, which does not necessitate precise measurement.

A callback is provided for when location updates arrive, in the form of a method which belongs to the LocationListener interface, which the activity implements.

When a new location update arrives, the distance between it and the last location is calculated. This is added to a running total of distance traveled. The estimated return time is updated by using a predetermined estimate of average walking pace, assuming an immediate turnaround. Finally, the latest location and related data are uploaded to Firebase.

When a new locatiaon is uploaded to Firebase, an event is triggered which causes the activity to download new locations and update the map and estimated return time. This code is shared by the observer and the hiker, simplifying their display of progress and current location.

At present, return time estimation is done in a relatively crude fashion. Return time is based on a calculation which assumes immediate turnaround, and is based on a constant walking pace. This is functional as a proof-of-concept, however future iterations of the app will need to provide smarter and more accurate estimates.

There is a camera button within the map screen. When pressed, the user is shown a camera activity which allows the user to take a picture. When a picture is taken, it is saved and a thumbnail is displayed on the map for both the hiker and the observer. Multiple photographs in the same general location are grouped together under a single thumbnail, along with an indicator of how many photographs are there. When a user taps a thumbnail they are taken to a gallery activity that shows all of the photos at that location.

The TrackMe app also runs an Android Foreground Service. A foreground service is a service which continues to run regardless of the foreground or background status of the app it is attached to, whereas other service types in Android will be shut off if their app is backgrounded for too long. The service listens for incoming connections and handles two types of requests: requests for time/distance updates, and requests to upload a new picture.

For time/distance requests, the service merely returns the current time and the distance traveled. When an image is to be uploaded, the service receives the data and saves the image file using the same path used for the camera activity, then triggers the handlers which generate a thumbnail and place the image on the map.